FLOOD CONTROL

CONNECTICUT RIVER VALLEY

REPORT OF SURVEY

AND

COMPREHENSIVE PLAN

APPENDIX, VOLUME 2

SECTION 4 – RESERVOIRS – DETAILS AND ESTIMATES

SECTION 5 – DIKES – DETAILS AND ESTIMATES

SECTION 6 – CHANNEL IMPROVEMENTS

UNITED STATES ENGINEER OFFICE
PROVIDENCE, RHODE ISLAND

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SECTION 4

DETAILS AND COSTS OF DAMS AND RESERVOIRS

1. Data available for design.- Adequate topographic maps have been available, rock profiles have been determined by diamond-drill borings and geophysical investigations, and the character of foundations determined by wash borings in soil, and the taking of samples from the borings. Foundation test pits and auger borings have also been made for foundation exploration, and for location and estimate of quantity of borrow material. Samples have been examined in the Soils Laboratory to determine suitability of the material for embankment construction and to determine permeability, consolidation and shear strength of the foundation strata. The foundation explorations and investigations of materials have been sufficient to permit determination of safe and economical design.

2. Basis of estimates.- The cost of each dam has been estimated upon the basis of a design which will provide the most economical and safest construction for the particular site. Estimates of quantities have been made upon the basis of the net outlines of the adopted designs and foundation requirements.

3. Unit prices.- Unit prices are based upon construction costs for similar types of work in New England and elsewhere, particular use being made of cost data from the Quabbin Reservoir, under construction by the Metropolitan Water Supply Commission of Boston, Massachusetts, and from the Muskingum Flood Control Project, Ohio. In determining unit prices for borrow material, account has been taken of the fact that much of it occurs in relatively thin layers of glacial deposits containing boulders, and the irregularity of such deposits and difficulty of transportation over rugged terrains have been considered.

The unit prices vary with the condition, type and method of construction, and availability and location of materials found at each site. Other considerations affecting the unit prices adopted are the amounts of material to be handled in one season's work at the various jobs, this factor being important in determining adequate plant cost. The fact that the advance of the general construction cost index has advanced almost to the 1927-1929 level has made desirable comparison with prices current on similar work performed at that time. In most cases the sites are readily accessible by existing roads and the item of access roads is covered by the unit prices.

4. Contingencies, engineering, and overhead.- Contingencies are estimated at 20 per cent on account of the preliminary character of the foundation exploration and design and the construction difficulties anticipated. A caretaker's dwelling will be required in some cases and this item is included in the estimate for contingencies. Some consideration has been given to the present upward prices, but a rise of the cost index of November 1936 of more than 5 to 8 per cent has not been anticipated. Engineering and overhead costs are estimated at 15 per cent of the construction costs.

5. Rights of way.- The estimates of land and buildings are based upon information furnished by the States, upon assessed valuations, and upon field reconnaissance. Inasmuch as the spillways will not be topped except by floods of rare occurrence, it is not contemplated that it will be necessary to purchase land above the elevation of spillway lip. A damage caused by flooding above spillway can be compensated for as special damages by the several States more economically than by purchase of the lands. The areas listed to be purchased are considerably larger, however, than the areas actually flooded, for the reason that when a farm is being flooded in part, usually the most valuable land is taken, and

the farm's usefulness as such is destroyed. It is therefore generally just as economical to purchase the entire farm. The areas are estimated upon that basis, principally upon the advice of the State of Vermont, based upon its experience in connection with flood control at Montpelier. Arrangements will undoubtedly be made to continue farming on much of the land within the reservoirs, so that a cheaper solution of the land problem than the one shown in the estimates seems possible and probable. Water rights owned by private interests have been estimated for purchase upon the basis of assessed valuations, allowing a reasonable increase. Purchase of existing water power interfered with has been based upon a value of $50 per water horse-power. The addition for legal, overhead, and general expense has been estimated at 20 per cent.

6. Highway, railroad, and utility relocation.- The estimates have been made with the aid of the State and private interests involved. Relocation in kind has been estimated, and in certain cases betterment of existing road facilities has been covered, for which credit by the State involved may be anticipated. In the estimates for relocations of highways due regard has been had for the wishes of the States, and the estimates are considered adequate. In many cases a cheaper solution of the road problem appears possible by leaving the more expensive roads within the reservoirs as they are, and building detour roads at the higher and safer elevations above the flooded areas. In view of the less complicated and more definite nature of the work, contingencies on road and railroad relocations have been estimated at 10 per cent, and engineering and overhead also at 10 per cent.

7. Basis of annual costs.- The annual charges have been computed on the following basis: the total capital cost of each reservoir is the cost as indicated in the estimates shown in this Section, to which has been added interest during construction at the rate of 4% and 5% respectively

for Federal and State costs. For dams and reservoirs that can be completed within one construction season no interest during construction has been added. For a two-season job 4% has been added for Federal expenditures and 5% for State and local expenditures, for three-season jobs 6% for Federal and 7-1/2% for State and local expenditures. The total capital cost thus arrived at has been amortized over a period of 50 years at 4% and 5% for Federal and State costs respectively. Maintenance expenses have been computed on the following basis: for earth dams, the following annual charges have been used, depending on size of embankment quantities:

Up to		300,000	cu. yds.	--	$ 500
300,000	to	500,000	" "	--	1,000
500,000	to	750,000	" "	--	1,500
750,000	to	1,000,000	" "	--	2,000
1,000,000	to	1,500,000	" "	--	2,500
1,500,000	to	2,000,000	" "	--	3,000
2,000,000	to	2,500,000	" "	--	3,500

For gates and machinery annual maintenance costs have been estimated at 3%. For concrete dams, tunnels, walls and other concrete parts, the maintenance charges have been estimated at 1% of the cost of such dams or parts. For gate-operated dams a charge of $1500 per annum for an operator and $500 per annum covering stand-by charges, and expendable supplies, light, gas, oil, etc. A general overhead charge of $3000 for each dam has been assessed. Loss of taxes from the land occupied by the reservoirs has been estimated and is included in operating expense. At reservoirs where the maintenance cost of the new road system exceeds that of maintaining the now existing road system, such excess maintenance cost has been added to the annual charges for the reservoir.

8. Descriptive details of reservoirs and dams.- Pertinent factors in the construction of the several proposed reservoirs and alternates are briefly set forth in the following paragraphs:

(1) East Haven No. 18A - (a) General.- The East Haven Reservoir on the Passumpsic River, about 32.3 miles above its confluence with the Connecticut River, is outlined on Plate No. 55. The dam site is located about 2 miles south of East Haven, Vermont, and the reservoir extends upstream about three miles, all in the Towns of Burke and East Haven, in Caledonia and Essex County respectively. The 47.5 square miles of drainage area are hilly farm and forest land. As designed, the capacity is 6.1 inches of run-off from the watershed above, or 15,500 acre-feet. The flooded area of 500 acres at the spillway crest elevation 1040.0 m.s.l., is classified as follows:

(1) Agricultural land.....	300 acres, mostly of poor quality.
(2) Pastureland...........	Included in (1) above.
(3) Wooded Land...........	200 acres.
(4) Towns, etc............	Town of East Haven, including 30 sets of buildings, and cemetery of 200 graves.

(b) Highways and roads.- About 0.8 mile of 16-foot and 3.0 miles of 20-foot gravel road will be flooded. A tentative relocation is shown on reservoir map, Plate No. 55.

(c) Railroads.- No railroads are involved.

(d) Other public works.- 4 miles of telephone line will be relocated.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 56 and 57.

(1) Geology.- Rock occurs at or near the surface throughout the right bank abutment. The rock surface here dips downward, passes beneath the river at a depth of about 15 feet, and under the left end of the dam is situated at a great but undetermined depth below the surface. The overburden consists of pervious beds of sand, gravel, and boulders, fine

sand and rock flour being noticeably lacking. Hydraulic construction of the embankment is proposed, this choice being based upon the occurrence nearby of mixed materials suitable for hydraulic sluicing. The spillway and tunnel conduit will be constructed on the right bank, in nearly horizontal beds of micaceous schist.

(2) Available materials.- Glacial deposits of sand, gravel, rock flour, and boulders are available in the left hillside above the dam for hydraulic sluicing. Sand and gravel suitable for use as concrete aggregate may be obtained within 0.5 mile upstream. Rock excavations will supply a sufficient volume of rock required for riprap and toe construction.

(3) Dam and appurtenant works.- A hydraulic-fill dam with a saddle spillway on the right bank is proposed. The total length is 2030 feet. The top elevation is 1055.0 m.s.l., or about 103 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum flow line.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The hydraulic-fill embankment will be 30 feet wide on top, with side slopes of 1 on 3. The back or downstream section will consist of coarse rock with a rock-filled trench along the toe to provide for drainage. The upstream slope will be paved with riprap. A blanket of impervious material will extend upstream from the upper toe of the impervious core. Little ground preparation will be needed other than clearing of all vegetable material. Materials will be utilized from the excavation and adjacent borrow pits.

(6) Spillway.- An open spillway 110 feet long, of a concrete-ogee section, will be provided in a saddle on the right bank. The discharge will be carried around the dam in a concrete-lined channel and returned to the river below. With the permanent spillway crest at elevation 1040.0

m. s.l., the discharge under a 10-foot head, the maximum surcharge, will be 11,750 second-feet, or the equivalent of 245 second-feet per square mile of drainage area controlled. There will be a freeboard of 5 feet above the 10-foot surcharge. No control will be provided. The quality of the rock and the distance downstream from the dam at which the spillway discharge returns to the river are believed adequate to prevent any damage to the dam.

(7) Outlet.- A concrete-lined tunnel, 610 feet long, located in the right bank, and having a cross-sectional area of 72 square feet will provide for stream-control during the construction of the embankment and for reservoir-control later. No gates are provided, the reservoir acting as a retarding basin. Under the operating head, spillway-crest elevation, the outlet capacity will be 1,900 second-feet. A reinforced concrete stilling basin is provided at the discharge end to prevent scour. Trash racks will be provided to prevent clogging of the conduit.

(8) Plan of construction.- It is proposed to construct first the outlet and stilling basin for stream-control, prepare the ground for the embankment, then the spillway will be excavated and lined, using the spoil in the embankment. The upstream side of the embankment will be riprapped as the fill progresses. The time estimated for construction is 16 months or two construction seasons.

(9) Conservation storage.- Not feasible.

EAST HAVEN - No. 18A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	80 ac.	Lump Sum	$ 7,800	
	Stream control		" "	5,000	
	Excavation, earth	113,000 c.y.	$0.40	45,200	
	Excavation, rock	80,000 c.y.	2.30	184,000	
	Excavation, tunnel	2,500 c.y.	10.00	25,000	
	Embankment, hydraulic fill	1,175,000 c.y.	0.35	411,250	
	Riprap	29,000 c.y.	1.50	43,500	
	Concrete, plain	8,300 c.y.	10.00	83,000	
	Concrete, reinforced	3,000 c.y.	12.00	36,000	
	Reinforcing steel	300,000 lbs.	0.06	18,000	
	Miscellaneous		Lump Sum	2,500	
				861,250	
	Contingencies		20%	172,750	
				1,034,000	
	Engineering and overhead		15%	155,000	
	Total				$1,189,000
2.	Relocation of Railroads and Utilities				
	Telephone lines	4 mi.	Lump Sum	2,000	
	Contingencies		10%	200	
				2,200	
	Engineering and overhead		10%	200	
	Total				2,400
3.	Rights of Way and Land				
	Land	800 ac.	Lump Sum	24,000	
	Buildings purchased	30 sets	" "	50,000	
	Water rights		" "	5,000	
	Cemetery relocation	200 graves	" "	6,000	
				85,000	
	Legal, overhead, and general expense		20%	17,000	
	Total				102,000
4.	Highway Relocation				
	20-ft. gravel state highway	3 mi.	Lump Sum	125,000	
	16-ft. gravel town road	0.8 mi.	" "	24,000	
				149,000	
	Contingencies		10%	15,000	
				164,000	
	Engineering and overhead		10%	16,000	
	Total				180,000
5.	Grand Total Capital Cost				$1,473,400
6.	Total Annual Cost				$ 81,700

(2) Lyndon Center No. 21A.- (a) General.- The Lyndon Center Reservoir, on Millers Run, about 2-1/2 miles above its confluence with the Passumpsic River, is outlined on map, Plate No. 58. The dam site is located about three miles northwest from Lyndonville, Vermont, and the reservoir extends upstream about five miles, all in the Town of Lyndon, in Caledonia County. The 52 square miles of drainage area are hilly farm land at the headwaters of the Passumpsic. As designed, the capacity is 6.0 inches of run-off from the watershed above, or 16,600 acre-feet. The flooded area of 550 acres at the spillway crest elevation, 766.5 m.s.l., is classified as follows:

(1) Agricultural land..... 500 acres of considerable value, including 15 sets of buildings.

(2) Pastureland .... 50 acres.

(3) Wooded land .... Included in (2) above.

(4) Towns, etc. .... No community centers are within the area.

(b) Highways and roads.- About 4-1/2 miles of gravel state highway, 18 feet wide, will be flooded. A tentative relocation is sketched on the reservoir map, Plate No. 58.

(c) Railroads.- None would be involved.

(d) Other public works.- One-half mile of water main and five and one-half miles of electric power line will be relocated.

(e) Dam.- The general design of the dam, the area and capacity curves, and geological features are indicated on Plates Nos. 59 and 60.

(1) Geology.- Mica schist under a shallow cover of sand and soil forms the right abutment. The rock surface dips beneath the valley floor, reaching an undetermined depth. The river meanders in a flood plain, 600 feet wide, underlain by deposits of fine sand and rock flour. Above the flood plain similar deposits occur in low hills, between 40 and 60 feet high, on which the dam will be continued as a dike. Rock is

From there to the top the slopes will be 1 on 2-1/2 as a minimum. The upstream slope will be paved with riprap; the downstream slope sodded. A rock-filled trench will be provided along the downstream toe to insure drainage. The earth-fill spillway abutment sections are to be of a similar construction, except that the top width will be 20 feet. The materials for the embankment will be obtained for the most part from borrow, utilizing as much of the spoil from the outlet and spillway excavations as is suitable.

(6) Spillway.- An open, ogee section, concrete spillway with an apron, 205 feet long, will be constructed on ledge rock. It will carry the discharge around the left end of the dam, returning it to the main stream about one-half mile below the dam. The discharge capacity under an 8-foot surcharge will be 13,800 second-feet, or the equivalent of 265 second-feet per square mile from the drainage area controlled. The freeboard of 5 feet will be above this 8-foot surcharge. No control will be provided. As the spillway discharge returns to the stream one-half mile below the dam, it cannot affect the dam in any manner.

(7) Outlet.- A tunnel outlet will be provided through ledge rock at the right abutment of the main dam. An open intake channel will lead to the tunnel from about 500 feet above the upstream toe of the dam. A stilling basin will be provided at the discharge end of the tunnel. From there the discharge will be carried through an open channel to the main stream about 1,000 feet below the toe of the dam. The outlet capacity under maximum operating head, spillway crest, is 2,300 c.f.s. No gates will be provided, the reservoir acting as a retarding basin. A series of racks will be placed over the tunnel entrance to prevent clogging by debris.

(8) Tunnel.- The outlet will be 410 feet long, with 220 feet of tunnel through a mica schist formation, and 190 feet of cut and cover conduit on rock foundation. The section will be horse-shoe shaped, of reinforced concrete, with a net cross-sectional area of 50 square feet.

(9) Plan of construction.- It is proposed to construct first the outlet and prepare the foundation of the main dam, excavating the cut-off and drainage trenches. After the outlet is completed, the stream will be diverted through it, and the main dam will be built. As the main dam is being completed, the spillway will be constructed. The embankments will be riprapped as the fill progresses. The time required for construction will be about nine months.

(10) Conservation storage.- Not feasible. Analysis of the potential value shows that the power benefits are low, and that an increase in storage and spillway elevation is prohibitive in cost because the Village of Wheelock abuts the uppermost reaches of the reservoir.

(Table on following page)

LYNDON CENTER - No. 21A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing and grubbing		Lump Sum	$ 4,000	
	Stream control		" "	7,000	
	Excavation, earth	220,000 c.y.	$0.40	88,000	
	Excavation, rock	5,200 c.y.	3.00	15,600	
	Excavation, tunnel	900 c.y.	10.00	9,000	
	Backfill at structures	5,700 c.y.	0.60	3,420	
	Embankment, rolled fill	676,000 c.y.	0.45	304,200	
	Riprap	14,000 c.y.	3.00	42,000	
	Sodding	8 ac.	240.00	1,920	
	Concrete, plain	3,200 c.y.	12.00	38,400	
	Concrete, reinforced	2,300 c.y.	14.00	32,200	
	Reinforcing steel	230,000 lbs.	0.06	13,800	
	Miscellaneous		Lump Sum	2,500	
				562,040	
	Contingencies		20%	112,960	
				675,000	
	Engineering and overhead		15%	101,000	
	Total				$ 776,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission lines		Lump Sum	6,600	
	10-inch C.I. water main	2,500 ft.	" "	9,500	
				16,100	
	Contingencies		10%	1,600	
				17,700	
	Engineering and overhead		10%	1,800	
	Total				19,500
3.	Rights of Way and Land				
	Land	1,600 ac.	Lump Sum	86,000	
	Buildings purchased	18 sets	" "	70,000	
				156,000	
	Legal, overhead, and general expense		20%	31,000	
	Total				187,000
4.	Highway Relocation				
	20-ft. gravel state highway	5.5 mi.	Lump Sum	198,000	
	Contingencies		10%	20,000	
				218,000	
	Engineering and overhead		10%	22,000	
	Total				240,000
5.	Grand Total Capital Cost				$ 1,222,500
6.	Total Annual Cost				$ 68,000

(3) Victory No. 22A.- (a) General.- This reservoir is outlined on Plate No. 61. The dam site is located on the Moose River 17.3 miles above its junction with the Passumpsic, or about four miles north of North Concord, Vermont. The reservoir extends upstream about four miles, all in the Town of Victory, in Essex County. The 66 square miles of drainage area are mostly hilly to mountainous forest lands. Water rights for power development have been acquired by the New England Power Association, but no steps toward construction have been taken. As proposed herein, the storage capacity will provide for 7.0 inches of run-off from the watershed above, or 24,600 acre-feet from empty reservoir to spillway crest. The flooded area at the spillway crest, 1149.0 m.s.l., will be 1,820 acres, classified as follows:

(1) Agricultural land.....	1,200 acres, mostly of poor quality; abandoned; only two sets of buildings remain.
(2) Pastureland...........	Included in (1) above.
(3) Wooded Land...........	600 acres partially cut-over.
(4) Towns, etc............	None.

(b) Highways and roads.- About 4-1/4 miles of 18-foot graveled road, including one small bridge, joining the Villages of Victory and Gallup Mills, will be flooded out. It is proposed to relocate this section of highway along the west side of the reservoir. It will include one concrete bridge. The tentative relocation is shown on reservoir map, Plate No. 61.

(c) Railroads.- No railroads are involved.

(d) Other public works.- None.

(e) Dam.- A general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 62 and 63.

(1) Geology.- At the site, the Moose River flows over thick deposits of glacial drift. The thickness of the overburden below the river bed,

as revealed by subsurface explorations, is at least 74 feet. The overburden material is a mixture of sand, gravel and boulders, together with much rock flour or glacial silt. Nests of granite boulders occur throughout the area, being scattered over the surface and in the overburden. The overburden is well consolidated.

(2) Available materials.- The overburden materials are of suitable quality for use in rolled-fill embankment, and for concrete aggregate. The quantity available within one-half mile of the site greatly exceeds the demands of the project. Considerable flexibility in selecting the most suitable material is therefore possible. Materials for both the pervious and impervious sections of the dam occur in the same formation within close proximity. Concrete aggregates may also be obtained from this same formation by screening and washing. Rock for rock-fill embankment may be obtained on the site from the large quantity of boulders scattered over the surface of the ground.

(3) Dam and appurtenant works.- A rolled-fill earth dam across the main channel, with a side-hill spillway on the right bank, is proposed. The total length is 535 feet, 460 feet being earth fill. The top elevation is 1164.0 m.s.l., or about 46 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum flow line.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-fill embankment will be 20 feet wide on top. It will consist of an impervious core from top to bottom, with side slopes of 1 on 1-1/2, keyed into the ground with a cut-off section. The core will be backed by a pervious section on both up and downstream faces, the outside slope of each of which will be about 1 on 3. The upstream slope will be paved with riprap, and the outer layer of the downstream section will be built of heavy cobble or field stone, with a rock-filled trench along the toe to provide for drainage. Little

foundation excavation will be required other than for the cut-off and for the toe trench, the ground preparation consisting principally of grubbing all vegetable matter. Materials from the spillway excavation will be used for the embankment.

(6) Spillway.- An open, flat-weir spillway, 75 feet long, of concrete will be provided on the right bank. The discharge will be carried around the end of the dam in a reinforced-concrete-lined channel, and returned to the river below. With the permanent spillway crest at elevation 1149.0 m.s.l., the discharge capacity under a 10-foot head, the maximum flow line, will be 6,650 second-feet, or the equivalent of 100 second-feet per square mile from the drainage area controlled. There will be a freeboard of 5 feet above this 10-foot surcharge. No control will be provided. The spillway will discharge at a point about 250 feet below the toe of the dam. A stilling basin will be provided to obviate danger of scour.

(7) Outlet.- A concrete conduit 220 feet long, located in the right bank, and having a net cross-sectional area of 58 square feet, will provide for stream-control during the construction of the embankment and for reservoir control later. No gates are provided, the reservoir acting as a retarding basin. Under the operating head, spillway crest elevation, the outlet capacity will be 1,850 second-feet. A reinforced concrete stilling basin is provided at the discharge end to prevent scour. Trash racks will be provided to prevent clogging of the conduit.

(8) Plan of construction.- It is proposed to construct first the outlet and stilling basin for stream-control and to prepare the ground for the embankment; then the spillway will be excavated and lined, using the spoil in the embankment. The upstream side of the embankment will be riprapped as the fill progresses. The time estimated for construction is seven months, or one construction season.

(9) Conservation storage.- Conservation storage of 35,200 acre-feet, equivalent to 10 inches of run-off, which will raise the spillway elevation to 1166 m.s.l. can be provided at an additional cost of $363,000.

(Table on following page)

VICTORY - NO. 22A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	200 ac.	Lump Sum	$ 16,000	
	Stream control		" "	5,000	
	Excavation, earth and hardpan	93,000 c.y.	$0.40	37,200	
	Backfill at structures	12,000 c.y.	0.35	4,200	
	Embankment, earth	55,000 c.y.	0.60	33,000	
	Riprap	2,100 c.y.	3.00	6,300	
	Concrete, reinforced	11,400 c.y.	10.00	114,000	
	Reinforcing steel	768,000 lbs.	0.06	46,080	
	Drainage items		Lump Sum	2,000	
	Racks and miscellaneous steel		" "	1,500	
				265,280	
	Contingencies		20%	53,720	
				319,000	
	Engineering and overhead		15%	48,000	
	Total				$ 367,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	2,100 ac.	Lump Sum	63,000	
	Water rights, undeveloped		" "	2,500	
				65,500	
	Legal, overhead, and general expense		20%	13,500	
	Total				79,000
4.	Highway Relocation				
	Town road, 14 ft. gravel, bridge	4-1/4 mi.	Lump Sum	153,000	
	Contingencies		10%	15,000	
				168,000	
	Engineering and overhead		10%	17,000	
	Total				185,000
5.	Grand Total Capital Cost				$ 631,000
6.	Total Annual Cost				$ 37,800

trench will provide drainage. Materials for the embankment will be obtained from borrow pits within a quarter of a mile from the dam. Two short earth-fill sections, one at each end of the spillway, will be of rolled earth-fill, constructed in a manner similar to the main dam.

(6) Spillway.- An open spillway 300 feet long, of a concrete ogee section with apron, will be provided in a low saddle at the northeast side of the reservoir. The discharge will return to the river one mile below over a flat slope, and cannot affect the dam in any manner. With the permanent crest at elevation 900.0 m.s.l., the discharge capacity under a 6.0-foot surcharge, the maximum flood, will be 12,300 second-feet, or the equivalent of 490 second-feet per square mile for the watershed above. Five-foot freeboard is provided above the 6-foot surcharge. No control will be provided. The spillway will be protected from scour by an apron, and concrete abutment walls will protect the earth embankment.

(7) Outlet.- A reinforced concrete conduit, located in the right bank, will provide for stream-control during the construction of the embankment and reservoir-control later. The conduit will be of the spread horse-shoe shape. A net cross-sectional area of 63 square feet will provide a discharge capacity of 1,550 c.f.s. under the maximum head at spillway-crest elevation. An open channel will carry the water to the conduit and another similar channel will discharge it into the river below the dam. A stilling pool will be constructed at the downstream end of the conduit. No gates will be provided, the reservoir acting as a retarding basin. Trash racks will be provided to prevent clogging of the conduit.

(8) Plan of construction.- It is proposed to construct first the outlet and stilling pool. The stream will then be diverted through the conduit, and the embankment built. The spillway will be built simultaneously with the main dam. Riprapping will progress with the earth

fill. The estimated time for construction is seven months, or less than one working season.

(9) Conservation storage.- Not feasible. Limitations at the site prevent an increase of storage.

(Table on following page)

HARVEY LAKE - NO. 50

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing and grubbing		Lump Sum	$ 2,000	
	Stream control		" "	4,000	
	Excavation, earth	40,000 c.y.	$0.40	16,000	
	Backfill at structures	1,700 c.y.	0.60	1,020	
	Embankment, rolled fill	36,000 c.y.	0.60	21,600	
	Riprap	2,200 c.y.	4.00	8,800	
	Sodding	3 ac.	240.00	720	
	Concrete, plain	5,100 c.y.	10.00	51,000	
	Concrete, reinforced	600 c.y.	12.00	7,200	
	Reinforcing steel	60,000 lbs.	0.06	3,600	
	Miscellaneous		Lump Sum	2,000	
				117,940	
	Contingencies		20%	23,560	
				141,500	
	Engineering and overhead		15%	21,500	
	Total				$ 163,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission lines	1 mi.	Lump Sum	500	
	Contingencies		10%	50	
				550	
	Engineering and overhead		10%	50	
	Total				600
3.	Rights of Way and Land				
	Land	70 ac.	Lump Sum	4,900	
	Buildings purchased	35 sets	" "	68,000	
	Water rights		" "	2,000	
				74,900	
	Legal, overhead, and general expense		20%	15,100	
	Total				90,000
4.	Highway Relocation				
	18-foot gravel state highway	0.7 mi.	Lump Sum	25,200	
	Contingencies		10%	2,500	
				27,700	
	Engineering and overhead		10%	2,800	
	Total				30,500
5.	Grand Total Capital Cost				$ 284,100
6.	Total Annual Cost				$ 19,800

(5) Bethlehem Junction No. 24A.- (a) General.- The Bethlehem Junction Reservoir on the Ammonoosuc River, about 35.7 miles above its confluence with the Connecticut River, is outlined on Plate No. 67. The dam site is located about 3-1/2 miles east of Bethlehem, New Hampshire, and the reservoir extends upstream about five miles, all in the Towns of Bethlehem and Carroll, in Grafton and Coos County, respectively. The 90 square miles of drainage area are mostly hilly to mountainous forest lands. As designed, the capacity is 6.0 inches of run-off from the watershed above, or 28,800 acre-feet. The flooded area of 860 acres at the spillway crest elevation, 1356.0 m.s.l., is classified as follows:

(1) Agricultural land..... 480 acres of poor quality.

(2) Pastureland........... Included in (1) above.

(3) Wooded land........... 380 acres.

(4) Towns, etc. .... 19 sets of buildings located within the reservoir.

(b) Highways and roads.- Relocation of about 4.8 miles of 20-foot concrete highway will be required. A tentative relocation is shown on the reservoir map, Plate No. 67.

(c) Railroads.- An abandoned branch line of the Boston & Maine Railroad lies in the reservoir basin.

(d) Other public works.- Eight miles of telephone and 4 miles of transmission lines will be relocated.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 68 and 69.

(1) Geology.- The rock profile has been constructed from data obtained by geophysical methods of prospecting, supplemented by information from several borings. Subsurface investigations are now being extended by core boring methods, but complete information is not available as yet.

Granite is exposed on the right side about 0.6 miles from and about 365 feet above the river. The rock surface dips downward and passes beneath the stream at a depth of 100 feet or more. On the left bank the overburden is composed of pervious sand and gravel, whereas that on the right is made of finer grained and less permeable material. Fine sand and rock flour or silt, together with some gravel and boulders, occurs as a compact formation below river level.

(2) Available materials.- The proposed spillway is located on the far right bank where it can be cut in rock which underlies an overburden of sand, gravel, and rock flour. These materials, excavation of which is required for the spillway approach and channel, are available for sluicing into the embankment. The conduit will be located on the right bank, in rock, the location of which is still being investigated by borings. Concrete aggregate are available on the left bank within 0.5 mile. Rock from excavations supplemented by boulders will be available for riprap and toe construction.

(3) Dam and appurtenant works.- A hydraulic-fill dam with a side-channel spillway on the right bank is proposed. The total length is 2,030 feet. The top elevation is 1373.0 m.s.l., or about 163.0 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum flow line.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The hydraulic-fill embankment will be 30 feet wide on top, with side slopes of 1 on 3, and with two 10-foot berms on the downstream slope. The upstream slope will be paved with riprap, the downstream slope sodded. A rock-filled trench will be provided along the downstream toe to insure drainage. Little ground preparation will be needed other than clearing of all vegetable material.

(6) Spillway.- A 155-foot side-channel spillway will be constructed in the ledge rock on the right bank. It will discharge flood water into an open concrete-lined channel which will carry it around the end of the dam and return it to the river below. With the permanent crest at elevation 1356.0 m.s.l. the discharge capacity under a 12-foot surcharge, the maximum flood, will be 20,200 second-feet or the equivalent of 225 second-feet per square mile for the watershed above. Five feet of freeboard is provided above the 12-foot surcharge. No control will be provided. The distance downstream from the dam to the point where the spillway discharge returns to the river is believed adequate to prevent any damage to the dam.

(7) Outlet.- A concrete-lined tunnel 1,310 feet long, excavated through rock and earth in the right bank, and having a cross-sectional area of 100 square feet, will provide for stream-control during the construction of the embankment and for reservoir-control later. No gates are provided, the reservoir acting as a retarding basin. Under the operating head, spillway-crest elevation, the outlet capacity will be 3,200 second-feet. A reinforced concrete stilling basin is provided at the discharge end to prevent scour. Trash racks will be provided to prevent clogging of the conduit.

(8) Plan of construction.- It is proposed to construct first the outlet and stilling basin for stream-control, prepare the ground for the embankment, then the spillway will be excavated and lined, using the spoil in the embankment. The upstream side of the embankment will be riprapped as the fill progresses. The time estimated for construction is 18 months or two construction seasons.

(9) Conservation storage.- A lake for recreational purposes can be maintained during the summer season to the extent of 1-1/2 inches of run-off or 7,200 acre-feet at an additional cost of $752,000. The lake will extend to Elevation 1305 and cover approximately 210 acres.

BETHLEHEM JUNCTION - No. 24A

COST ESTIMATE

Item: No.:	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	250 ac.	Lump Sum	$ 25,000	
	Stream control		" "	15,000	
	Excavation, earth	335,300 c.y.	$0.40	134,120	
	Excavation, rock	35,200 c.y.	2.30	80,960	
	Excavation, tunnel	16,900 c.y.	10.00	169,000	
	Embankment, hydraulic fill	1,620,000 c.y.	0.45	729,000	
	Riprap	31,700 c.y.	1.50	47,550	
	Sodding	10 ac.	240.00	2,400	
	Concrete, plain	5,000 c.y.	10.00	50,000	
	Concrete, reinforced	14,200 c.y.	12.00	170,400	
	Reinforcing steel	2,130,000 lbs.	0.06	127,800	
	Miscellaneous		Lump Sum	5,000	
				1,556,230	
	Contingencies		20%	310,470	
				1,866,700	
	Engineering and overhead		15%	280,000	
	Total				$2,146,700
2.	Relocation of Railroad and Utilities				
	Telephone lines	8 mi.	Lump Sum	4,000	
	Transmission lines	4 mi.	" "	2,000	
				6,000	
	Contingencies		10%	600	
				6,600	
	Engineering and overhead		10%	800	
	Total				7,400
3.	Rights of Way and Land				
	Land	1,300 ac.	Lump Sum	69,000	
	Buildings purchased	19 sets	" "	57,000	
				126,000	
	Legal, overhead and general expense		20%	25,000	
	Total				151,000
4.	Highway Relocation				
	20-ft. concrete state highway	4.8 mi.	Lump Sum	313,200	
	Contingencies		10%	31,300	
				344,500	
	Engineering and overhead		10%	34,500	
	Total				379,000
5.	Grand Total Capital Cost				$2,684,100
6.	Total Annual Cost				$ 147,000

(6) Groton Pond No. 27A.- (a) General.- The Groton Pond reservoir, on the Wells River, Vermont, is outlined on Plate No. 73. It is located about two miles northwest from Ricker Mills, Vermont, in the Town of Groton, in Caledonia County. The 17.3 square miles of drainage area are mostly hilly woodland at the headwaters of the Wells River. The existing pond is an attractive resort, with summer cottages and boat houses along its edge. Water rights of the existing development are vested in the Green Mountain Power Corporation of Vermont. As designed, the storage capacity will provide for seven inches of run-off, or 6,500 acre-feet. The flooded area at the spillway crest will be 560 acres, classified as follows:

(1) Agricultural lands..... None.

(2) Pastureland............ None.

(3) Wooded land............ 200 acres outside the existing pond area; mainly brush, cut-over birch and poplar.

(4) Towns, etc. .... 68 summer cottages and boat-houses now scattered around the pond.

(b) Highways and roads.- No highways and roads are involved.

(c) Railroads.- No railroads are involved.

(d) Other public works.- The existing low dam, now owned by the Green Mountain Power Corporation, must be acquired.

(e) Dam.- The general design of the dam, the area and capacity curves and the geological features are indicated on Plates Nos. 74 and 75.

(1) Geology.- Ledge rock, consisting of massive granite, occurs at or near the surface over a large area. The granite formation is strikingly uniform in character, and virtually free from cracks or other evidences of weakness. The rock is of such quality that it could easily withstand the loads and other structural demands imposed

by a much larger dam. The profile indicates that the rock surface extends outward at nearly the same elevation. Rock has been traced throughout a major part of the foundation area. The thickness of the overburden varies from zero to about seven feet. It is of glacial origin, especially that which occurs in the extreme abutment areas, and consists of a mixture of sand and gravel, in part, stratified; many boulders occur, as well as detached blocks of ledge rock.

(2) Available materials.- Suitable earth borrow materials for the soil portion of the rock-fill section are available in more than ample quantities adjacent to the site. Concrete aggregate may be obtained nearby, but the separation into fine and coarse aggregate and the elimination of superfine sand by washing will be necessary. The large number of boulders scattered throughout the area, and rock from the excavations can be used as fill in the rock embankment.

(3) Dam and appurtenant works.- A rock-fill and concrete dam is proposed at the site of the existing dam; it will have a concrete spillway 200 feet long at the central section. The total length will be 1,090 feet, 500 feet being the total length of the two rock-fill sections, and 590 feet the total length of the concrete spillway and retaining sections. The top elevation of the rock-fill sections is 1094.0 feet m.s.l., and the concrete retaining section 1089.0 feet m.s.l., making the maximum height of the dam about 19 feet above the stream bed. This will allow a freeboard above the maximum flood-line of 5 feet for the rock-fill sections.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rock fill will be 20 feet wide on top, with side slopes of 1 on 2 upstream and 1 on 1-1/2 downstream. The back, or downstream section, will consist of coarse field-rocks and boulders, with side slopes of 1 on 1-1/2. Against the inner face of the coarse

rock fill will be a section of graded material varying from coarse gravel to fine sand, and finally an impervious layer about 5 feet thick with an upstream slope of 1 on 2. The upstream slope will be paved with riprap. Little ground preparation will be needed, other than grubbing of all vegetable matter. Materials will be utilized from the excavation and adjacent borrow pits. The coarse rock-fill will provide ample drainage.

(6) Spillway.- An open, ogee type spillway, 200 feet long, in the concrete gravity section of the dam, will provide for a discharge of 6,000 second-feet, under a 4-foot surcharge. This is the equivalent of 350 second-feet per square mile from the watershed above.

(7) Outlet.- The outlet will consist of six openings through the spillway section, totaling 30 square feet in area, which will provide stream-control during construction and pond-control later. No gate-control is provided, as the reservoir will operate as a retarding basin. The outlet capacity under maximum head at spillway elevation is 660 second-feet.

(8) Plan of construction.- It is proposed first to prepare the ground and construct the rock-fill sections, using the existing gate to provide stream-control. The concrete outlet section will then be placed and the stream diverted through it. The remainder of the dam will then be completed. The time required for construction is estimated at six months, or one construction season.

(9) Conservation storage.- Conservation storage of 6,350 acre-feet, equivalent to 7 inches of run-off over the drainage area, will raise the spillway to elevation 1096 m.s.l., and can be provided at a cost of $144,000, increasing the total estimated cost for the development to $260,000.

GROTON POND - NO. 27A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	4 ac.	Lump Sum	$ 1,000	
	Stream control		" "	1,000	
	Excavation, earth	2,100 c.y.	$1.00	2,100	
	Excavation, rock	400 c.y.	3.00	1,200	
	Embankment, rock fill	6,500 c.y.	1.70	11,050	
	Riprap	1,450 c.y.	3.00	4,350	
	Concrete, plain	2,200 c.y.	10.00	22,000	
	Concrete, reinforced	150 c.y.	12.00	1,800	
	Reinforcing steel	10,000 lbs.	0.06	600	
	Miscellaneous		Lump Sum	2,000	
				47,100	
	Contingencies		20%	9,400	
				56,500	
	Engineering and overhead		15%	8,500	
	Total				$ 65,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	160 ac.	Lump Sum	2,400	
	Buildings, - cottages and boathouses		" "	30,000	
	Water rights		" "	10,000	
				42,400	
	Legal, overhead and general expense		20%	8,600	
	Total				51,000
4.	Highway Relocation				None
5.	Grand Total Capital Cost				$ 116,000
6.	Total Annual Cost				$ 10,200

(7) South Branch No. 28A.- (a) General.- The reservoir is located on the South Branch of Waits River, Vermont, 1-1/2 miles above the junction with Waits River, as outlined on Plate No. 76. The dam site is located about 0.2 mile upstream from a bridge on the Bradford-South Corinth Road. The reservoir extends upstream about 3.0 miles, and lies in the Towns of Corinth and Bradford, in Orange County. The 45 square miles of drainage area is mountainous and heavily wooded. As designed, the storage capacity will be equivalent to six inches of run-off from the watershed, or 14,400 acre-feet at spillway-crest elevation, 810 m.s.l. At this elevation the flooded area will be 520 acres, of which about 250 acres is wooded.

(b) Highways and roads.- The reservoir will inundate a section of a 22-foot gravel road, about 3-1/2 miles in length, and four bridges. It will be necessary to relocate a new highway on the left bank 2.5 miles in length, of which 1.1 miles is improved existing road. In addition, there will be three short stretches of highway relocation on the right bank, totaling 1.5 miles in length. All the relocated roads will be gravel surfaced, 16 and 22 feet wide, and will include four small concrete bridges. The tentative relocations are indicated on reservoir map, Plate No. 76.

(c) Railroads.- No railroads will be involved.

(d) Other public works.- None.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 77 and 78.

(1) Geology.- Rock is exposed in the river near the proposed centerline of the dam. Borings indicate a broad but rather irregularly eroded and disintegrated rock floor. Near the end of the dam, on the right bank, sound rock occurs about 30 feet above river level beneath 25 to 30 feet

of disintegrated rock. On both sides of the stream the overburden is comprised of a compact mixture of sand, gravel, rock flour, and boulders. On the right bank two borings disclosed 30 to 40 feet of very soft, greatly weathered mica schist overlying sound rock.

(2) Available materials.- Suitable material for both impervious and pervious rolled-fill construction is available upstream and downstream within 0.5 mile. Rock for riprap and toe construction may be obtained from spillway and conduit excavations and as well as from boulder accumulations. Sand and gravel are available within 1.0 mile for use as concrete aggregate after screening and washing.

(3) Dam and appurtenant works.- A rolled-fill earth dam is proposed, having a length of 810 feet, top elevation at 825.0 m.s.l., and a maximum height of 95 feet. This will allow a freeboard of five feet above the maximum flood level. The spillway will be a concrete "Morning Glory" type, situated on the right bank, and the outlet will be a concrete conduit.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The main dam, a rolled-fill structure, will be 25 feet wide on top. It will consist of an impervious core keyed into impervious foundation, with pervious shoulders. Where ledge rock is at or near the surface a concrete key wall will be used. The outside slopes of the dam are 1 on 3 from the bottom up to within 15 feet of the top, the top 15 feet being 1 on 2-1/2. The upstream slope will be riprapped. A rock-filled trench will be constructed along the downstream toe to provide for drainage. Earth and rock excavated on the job will be used in the dam. Across a saddle located on the left bank, about 320 feet from the dam, an earth dike, 140 feet long and 10 feet high, will be constructed. The top of this dike will be at Elevation 820, five feet below the top of the main dam, thus providing additional safety to the main dam in the event of exceptionally high water.

(6) Spillway.- The spillway will consist of a reinforced concrete "Morning Glory", 42.5 feet in diameter, discharging into an 18-foot diameter conduit embedded in rock. The crest will be at Elevation 810.0 m.s.l. With a surcharge of ten feet, maximum flood level, the spillway will have a discharge capacity of 12,100 c.f.s., or the equivalent of 269 second-feet per square mile from the drainage area controlled. The spillway intake will be located on the right bank near the toe of the dam. The spillway discharge will return to the river 200 feet below the dam.

(7) Outlet.- An outlet, consisting of a reinforced concrete conduit having a cross-sectional area of 72 square feet and founded on rock, will be provided to draw down the reservoir. No gate control will be provided. The water passing through this service conduit will run into the spillway conduit, and thence through a stilling basin to the river bed. There will be a trash rack at the intake. The outlet capacity under maximum operating head, spillway crest, will be 1,900 second-feet.

(8) Plan of construction.- It is proposed to construct the conduit back into the bank far enough so that cofferdams will be necessary only at the trash rack and stilling basin. When the stream is diverted through the conduit, the placing of embankment will commence. It is estimated that the construction will require eight months, or one working season, to complete.

(9) Conservation storage.- Not feasible. The cost of additional storage makes an increase in reservoir capacity impracticable.

SOUTH BRANCH - NO. 28A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	100 ac.	Lump Sum	$ 8,000	
	Stream control		" "	5,000	
	Excavation, earth	55,500 cy	$0.40	22,200	
	Excavation, rock	4,200 cy	3.00	12,600	
	Embankment, rolled-fill	290,000 cy	0.50	145,000	
	Riprap (hand placed)	7,100 cy	3.00	21,300	
	Concrete, plain	1,300 cy	10.00	13,000	
	Concrete, reinforced	6,800 cy	12.00	81,600	
	Reinforcing steel	680,000 lbs.	0.06	40,800	
	Miscellaneous		Lump Sum	5,000	
				354,500	
	Contingencies		20%	70,900	
				425,400	
	Engineering and overhead		15%	63,600	
	Total				$ 489,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	800 ac.	Lump Sum	20,000	
	Buildings purchased	9 sets	" "	24,000	
	Water rights		" "	5,000	
				49,000	
	Legal, overhead and general expense		20%	10,000	
	Total				59,000
4.	Highway Relocation				
	Town roads, gravel	4 mi.	Lump Sum	125,000	
	Contingencies		10%	13,000	
				138,000	
	Engineering and overhead		10%	14,000	
					152,000
5.	Grand Total Capital Cost				$700,000
6.	Total Annual Cost				$ 40,300

(8) Union Village No. 48.- (a) General.- Union Village Reservoir, on the Ompompanoosuc River, about 4 miles above its junction with the Connecticut, is outlined on Plate No. 79. The dam site is located about 1/4 mile north of Union Village, Vermont, and the reservoir extends upstream 3-1/2 miles, all in the Town of Thetford in Orange County. The drainage area of about 126 square miles is generally rugged. The hill tops are wooded, but the valleys are farmed, and a number of village centers are scattered over the area. As proposed, the storage capacity will be about 4-1/2 inches of run-off from the watershed, or 30,200 acre-feet at the spillway crest elevation. The flooded area at spillway-crest elevation, 543.0 m.s.l., will be about 600 acres, of which 250 acres are cleared, and 350 acres are wooded, and includes seven sets of buildings. The land is used principally for dairying purposes and is of no great economic importance. No villages will be flooded by this proposed reservoir.

(b) Highways and roads.- A total length of about 4 miles of secondary highway, including 5 bridges, will be flooded. Since the main purpose of these roads is to serve those farms in the reservoir area, it is believed that after the area is converted to reservoir use, one connecting link located along the west edge will be adequate. About 3 miles of secondary type highway as tentatively relocated is indicated on the reservoir map, Plate No. 79. Highway relocation will consist of improving 1.3 miles of an existing highway on the west side of the reservoir, and relocating a one-mile stretch of the same highway at the northwest end of the reservoir, connecting with a local road at Rice's Mills. One bridge will be included in the highway relocation.

(c) Railroads.- None will be involved.

(d) Other public works.- Five miles of telephone and transmission line will require relocation.

(c) Dam.- The general design of the dam, the area and capacity curves, and the geologic features are indicated on Plates Nos. 80 and 81.

(1) Geology.- Mica schist forms the left abutment of the dam, the rock surface rising steeply from the river's edge to heights of 250 feet or more. In the right abutment, the rock surface rises from a depth of 20 feet below the river at the bank to near spillway elevation, about 1,500 feet out from the river's edge. Above bed-rock, the right abutment consists of (1) pervious deposits of sand and gravel that extend from below the river bed to near the top of the dam, and (2) relatively impervious and compact mixtures of sand, rock flour, and some gravel in the adjacent higher ground. The spillway and outlet tunnel will be in rock at the left abutment.

(2) Available materials.- Material for impervious rolled-fill is available in the uppermost terrace on the right bank, Pervious materials may be obtained within 0,5 mile of the site both up and downstream. These deposits, composed of sand and gravel, are also suitable for concrete aggregate, although screening and washing will be necessary.

(3) Dam and appurtenant works.- A rolled-fill earth dam across the main channel, provided with a "morning glory" type of spillway in the left abutment is proposed. The dam will be 915 feet long, the top elevation at 561.0 m.s.l. will be 155 feet above the stream bed. This will allow a freeboard of 5 feet above the maximum or spillway-design flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-fill embankment will be 30 feet wide on top. It will consist of an impervious core, and pervious shoulders covered with broken rock. On the right bank there is a layer of sand and gravel at the surface which makes it necessary to use a cut-off trench under the impervious core. A concrete cut-off wall, anchored in the rock

ledge, will extend across the river bed, and up the bank to the end of the embankment. The embankment slopes will be 1 on 3 from the bottom up to within 15 feet of the top and the top 15 feet will be 1 on 2-1/2. The upstream slope will be paved with riprap. A heavy rock fill will be provided at the downstream toe, composed of material excavated from the spillway and the outlet works. Earth excavated from the tunnel approaches and elsewhere will be used in the embankment when adaptable, but the major part of the rolled fill will be obtained from borrow-pits.

(6) Spillway.- The flood waters will pass over the 320-foot circular crest of a "morning glory" type spillway, and into a 34-foot diameter concrete-lined shaft in the rock ledge of the left abutment. This vertical shaft curves and becomes horizontal, with the invert at normal river elevation, and discharges into an open channel, returning to the river about 280 feet below the toe of the dam. The discharge at this point will not endanger or damage the dam. With the permanent crest at elevation 543.0 m.s.l., the discharge capacity under a surcharge of 13 feet, the maximum flood level, will be about 51,200 c.f.s., or the equivalent of 406 second-feet per square mile from the drainage area above. No spillway control will be provided.

(7) Outlet.- The outlet will consist of an approach channel and a concrete-lined tunnel in the left bank, discharging into the main spillway tunnel. The outlet will provide for stream-control during construction of the embankment, and for reservoir-control later. The conduit will be provided with a gate section, the discharge to be controlled by two gates each 7-1/2 by 10 feet, mechanically operated through a vertical shaft from a gate house near the axis of the dam. The discharge capacity of the outlet under maximum operating head, spillway crest elevation, will be 10,100 second feet.

(8) Tunnels.- The spillway tunnel will be drilled through a mica schist formation, and its length will be about 600 feet. The outlet tunnel will be drilled in the same formation and its length will be about 440 feet. At the approach end, trash racks will be provided. The cross-sectional area of this tunnel will be 152 square feet, and of a spread horseshoe shape.

(9) Plan of construction.- It is proposed first to construct the spillway and outlet simultaneously. After these are constructed the stream may be diverted through the outlet, and the earth-fill made. The upstream face of the embankment will be riprapped as the fill progresses. The time estimated for complete construction is about 16 months or two construction seasons.

(10) Conservation storage.- Preliminary studies indicate that a lake for recreational purposes can be provided, and that facilities to maintain the lake level automatically can be installed at an additional cost of approximately $10,000.

(Table on following page)

UNION VILLAGE - NO. 48

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	110 ac.	Lump Sum	$ 11,000	
	Stream control		" "	8,500	
	Excavation, earth	84,000 c.y.	$0.40	33,600	
	Excavation, rock	56,000 c.y.	2.30	128,800	
	Excavation, shaft and tunnel	32,000 c.y.	6.00	192,000	
	Embankment, rolled fill	1,008,000 c.y.	0.45	453,600	
	Riprap	27,600 c.y.	1.50	41,400	
	Concrete, plain	9,800 c.y.	10.00	98,000	
	Concrete, reinforced	9,200 c.y.	14.00	128,800	
	Reinforcing steel	900,000 lbs.	0.06	54,000	
	Gates and machinery		Lump Sum	86,000	
	Gate house and miscellaneous		" "	15,000	
				1,250,700	
	Contingencies		20%	250,300	
				1,501,000	
	Engineering and overhead		15%	225,000	
	Total				$1,726,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission lines	5.0 mi.	Lump Sum	1,550	
	Contingencies		10%	150	
				1,700	
	Engineering and overhead		10%	200	
	Total				1,900
3.	Rights of Way and Land				
	Land	800 ac.	Lump Sum	40,000	
	Buildings purchased	7 sets	" "	25,000	
	Water rights		" "	5,000	
				70,000	
	Legal, overhead and general expense		20%	14,000	
	Total				84,000
4.	Highway Relocation				
	14 ft. gravel highway	1.8 mi.	Lump Sum	33,000	
	20 ft. gravel highway, structures	1.0 mi.	" "	76,000	
				109,000	
	Contingencies		10%	11,000	
				120,000	
	Engineering and overhead		10%	12,000	
	Total				132,000
5.	Grand Total Capital Cost				$1,943,900
6.	Total Annual Cost				$ 109,900

(9) Gaysville No. 29A.- (a) General.- Gaysville Reservoir, on the main stream of the White River, about 31.6 miles above its junction with the Connecticut, is outlined on Plate No. 82. The dam site is located about 1/2 mile southwest of Gaysville, Vermont, and the reservoir extends up the main stream about 10 miles, to the Village of Talcville, and up the Tweed River to within 2 miles of Pittsfield. For the most part, it lies in the Towns of Stockbridge and Rochester in Windsor County, and a small portion lies along the Windsor-Rutland county-line in the Town of Pittsfield of Rutland County. The 226 square miles of drainage area are mostly rough mountainous terrain embracing a number of sizable mill villages scattered along the lower reaches of the main streams. As proposed, the storage capacity would provide for about 6.5 inches of run-off from the watershed above, or about 77,800 acre-feet at the spillway crest elevation. At spillway elevation, 795.0 m.s.l., the reservoir will flood 1800 acres of a narrow valley. About 80 percent of this land is cleared, of which about half is cultivated and the remainder used for pasture. Parts of the three small villages of Stockbridge, Tupper, and Emerson, would be flooded. Generally the farms are of medium size and include wood lots on the mountain side above the reservoir high-water mark. Since all the best land would be flooded, including the farm buildings, it is thought probable that the hillside lots would have to be purchased as well as the bottom lands and farms. Estimated land damages include such lands above high-water mark where it is thought equitable.

(b) Highways and roads.- About 10 miles of through state-highway from Gaysville to Talcville will be flooded; also, about 3 miles of a branch up the Tweed River, and about 1-1/2 miles of connecting road up Stony Brook. About 0.7 of a mile of this state highway above Gaysville is of bituminous macadam, the remainder being of gravel.

It is estimated that a total of about 17 miles of relocation will be necessary, of which about 13 miles will be gravel construction, 0.7 of a mile bituminous macadam, and a little over 3 miles will be secondary connecting road. Because of the rugged terrain, a number of expensive bridge structures will be necessary. With respect to the estimated cost of highway relocation for Gaysville, the estimate considers reproducing highway facilities of a character equivalent to those now existing. It is understood that the estimated cost of relocation calculated by the State of Vermont includes some improvement of existing facilities, which has been tentatively valued by the State at approximately $300,000. The tentative relocations are indicated on reservoir map, Plate No. 82.

(c) Railroads.- About 13 miles of old, abandoned railroad, extending up the main stem of the reservoir, and up the arm on Tweed River, will be flooded. The old line has not been in use for years, little value remaining, so no charge has been made in the reservoir costs for this railroad.

(d) Other public works.- About 23 miles of telephone line will require relocation.

(e) Dam.- A general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 83 and 84.

(1) Geology.- At the dam site the river flows in a post-glacial rock gorge. Both right and left abutments are in metamorphic rock or schist, which occurs at a shallow depth beneath the river. A thin veneer of sand and gravel, lying on bed-rock, occurs high on the right abutment. The more ancient or pre-glacial channel of the White River lies approximately 0.25 mile to the northwest, through a saddle beyond a rock hill. Here bed-rock descends beneath fine sand and gravel to a depth of more than 80 feet below the valley floor. The spillway channel will be excavated in rock in the right abutment. The foundation, com-

posed of closely folded crystalline schist is of satisfactory quality for a concrete arch dam. Preparation of rock surfaces may entail grouting operations to seal seams and cracks below the surface.

(2) Available materials.- Concrete aggregate is available in large gravel deposits in and along the river, and 0.5 mile upstream from the site. In general, the river deposits are coarse, and contain a large number of boulders and cobbles suitable for crushed coarse aggregate. Finer aggregates of sand and gravel occur upstream in two low river terraces. Material for the earth dike may be obtained near and below the site.

(3) Dam and appurtenant parts.- A variable-radius concrete-arch dam is proposed for the main channel, with a concrete, gravity overflow-section, spillway on the right bank. Across the saddle, located on the left bank, about 600 feet from the dam an earth dike 545 feet long will be constructed. The main dam will be 875 feet long, 325 feet being gravity section. The 550-foot arch section is designed with an ample factor of safety, with provision for a surcharge of 3 feet of water over the top. The arch section will be 12 feet wide on top, and will be keyed into sound rock to a depth of 10 feet or more at the abutments, and across the river bottom. The elevation of the top of the dam will be 805.0 m.s.l., 170 feet above the stream bed.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The earth dike will be of rolled-fill construction, 20 feet wide at the top. The top elevation will be at 813.0 m.s.l., thus allowing a freeboard of 5 feet above maximum flood level. The fill will consist of an impervious core keyed into the ground with a cut-off along the axis of the dike, and backed with pervious material on both faces, the outside slopes of which will be a minimum of 1 on 2-1/2. Both shoulders will be of rock taken from the excavation for the main dam.

(6) Spillway.- An overflow section of concrete gravity dam, 300 feet long, with a crest elevation at 795.0 m.s.l. will take care of most of the flood discharge under a surcharge of 12.7 feet. The remainder of the discharge will pass over the arch section at a depth of 2.7 feet. The total discharge capacity will be 57,000 second feet or the equivalent of 253 second feet per square mile from the drainage area above.

(7) Outlet.- The outlet will consist of 4 conduits through the base of the arch dam. Each will be 5 feet in diameter, and the total discharge capacity for the four conduits, under the maximum operating head at spillway crest elevation, will be 7,200 c.f.s. The outlet discharge will be controlled by sleeve valves, with butterfly valves as auxiliaries for emergency gates. The control house will be located immediately above the valves on the downstream side of the dam. Energy from the discharge will be dissipated by a stilling basin.

(8) Plan of construction.- It is proposed to divert the river flow around the site of the outlet until the outlet can be built and that section of the dam raised above ordinary flood heights. Then the dam will be completed in convenient sections including the spillway section. Finally, the dike in the saddle will be completed. It is estimated that the construction period will be about 16 months or two construction seasons.

(9) Penstocks.- The installation of penstocks and outlet facilities at this site for a future power installation is a comparatively simple matter, and no economic benefits can be obtained by installing these facilities now. Provisions for unwatering of the pond will be provided by the flood control outlet and are available without any additional cost.

(10) Conservation storage.- Conservation storage to the amount of 4.4 inches of run-off, or 53,000 acre-feet, can be provided with the spillway at Elevation 820, at an estimated additional cost of $1,329,400, or a total cost of $4,780,000 for the development.

(Table on following page)

GAYSVILLE - NO. 29A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	200 ac.	Lump Sum	$ 18,000	
	Stream control		" "	12,000	
	Excavation, earth	54,200 c.y.	$0.40	21,600	
	Excavation, rock	17,000 c.y.	2.50	42,500	
	Embankment, rolled fill	103,000 c.y.	0.45	46,350	
	Riprap	3,700 c.y.	1.50	5,550	
	Concrete, plain	97,000 c.y.	9.00	873,000	
	Concrete, reinforced	700 c.y.	15.00	10,500	
	Reinforcing steel	300,000 lbs.	0.06	18,000	
	Gates and machinery		Lump Sum	90,000	
	Gate house and miscellaneous		" "	24,000	
				1,161,500	
	Contingencies		20%	232,500	
				1,394,000	
	Overhead and engineering		15%	209,000	
	Total				$1,603,000
2.	Relocation of Railroads and Utilities				
	Telephone lines	23 mi.	Lump Sum	10,400	
	Contingencies		10%	1,000	
				11,400	
	Engineering and overhead		10%	1,200	
	Total				12,600
3.	Rights of Way and Land				
	Land	2,400 ac.	Lump Sum	60,000	
	Buildings purchased	90 sets	" "	255,000	
	Water rights		" "	20,000	
				335,000	
	Legal, overhead, and general expense		20%	67,000	
	Total				402,000
4.	Highway Relocation				
	14-ft. gravel road, bridges	3.2 mi.	Lump Sum	102,000	
	20-ft. bit., mac., state highway	0.7 mi.	" "	49,000	
	20-ft. gravel state highway, bridges	12.9 mi.	" "	1,033,500	
				1,184,500	
	Contingencies		10%	118,500	
				1,303,000	
	Engineering and overhead		10%	130,000	
	Total				1,433,000
5.	Grand Total Capital Cost				$3,450,600
6.	Total Annual Cost				$ 208,400

(10) Ayers Brook No. 30A.- (a) General.- Ayers Brook Reservoir, on Ayers Brook, about 1.2 miles above its junction with the Third Branch of the White River, is outlined on Plate No. 85. The dam site is located about one mile north of Randolph, Vermont, and the reservoir extends upstream about four miles, all in the Town of Randolph in Orange County. The drainage area of 30 square miles is mostly hilly farm land, embracing several small village centers. As proposed, the storage capacity will provide for a 6.0-inch run-off from the drainage area above, or about 9,800 acre-feet between the spillway crest and empty reservoir. The flooded area to the spillway crest, 695.0 m.s.l., will be about 560 acres, classified as follows:

(1) Agricultural land..... Included in (2) below.

(2) Pastureland........... 500 acres of considerable value, including 10 sets of buildings.

(3) Wooded land........... 60 acres.

(4) Towns, etc. .... No community centers in the area.

(b) Highways and roads.- 4-1/4 miles of highways will require relocation, about 3-1/2 miles being of bituminous macadam construction, and the remainder secondary connecting road.

(c) Railroads.- No railroads will be involved.

(d) Other public works.- About 3-1/2 miles of telephone line must be relocated.

(e) Dam.- A general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 86 and 87.

(1) Geology.- The right abutment, which rises steeply from the river, is composed of schist. The rock surface dips steeply beneath the river. The left embankment is a flat terrace, 2200 feet wide and 50 feet high; this abutment terminates in a hill where rock is exposed above the top of the dam. The terrace consists entirely of fine sand and rock flour. The spillway and outlet conduit will be cut in the

schist of the right abutment.

(2) Available materials.- There is a scarcity of sand and gravel suitable for hydraulic construction. Fine sand and rock flour suitable for impervious rolled-fill are obtainable nearby. Coarse sand and gravel for the pervious embankment are available within 0.5 mile downstream. Rock fill for toe and outer shell construction will be obtained from spillway and outlet conduit excavations.

(3) Dam and appurtenant works.- A rolled-fill earth dam across the main channel, extending far up on the left bank is proposed, with a concrete side-channel spillway in the right bank entirely apart from the embankment. The length of the earth-fill is 2,640 feet; the top elevation at 707.0 m.s.l. is 70 feet above the stream bed, and will allow a freeboard of 5 feet above the spillway design flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-earth fill will be 20 feet wide on top. It will consist of an impervious core from top to bottom, keyed into the ground with a cut-off section about 10 feet deep along the axis of the dam, from river bed to left abutment. On the right, the cut-off will consist of a low concrete wall keyed into the rock ledge. The core will be backed by a section of pervious material on both the upstream and downstream faces, the outside slopes being 1 on 3 from bottom to within 15 feet of the top, and the top 15 feet 1 on 2-1/2. A rock-filled trench at the downstream toe will provide for subsurface drainage. Such of the spoil from the spillway excavation as is suitable will be utilized, but the materials for the embankment will be obtained for the most part from borrow pits.

(6) Spillway.- An open, concrete, ogee-section spillway, 125 feet long, will be built in the rock ledge of an adjacent saddle at the right. The spillway channel will carry the flood discharge from a few hundred

feet above the dam around to the right of the dam, returning it into a rock ravine off the natural channel of the main stream, where it will be allowed a free fall back to the main channel of the stream about 150 feet below the toe of the dam. With a permanent crest at elevation 695.0 m.s.l., the discharge capacity under a 7-foot surcharge, maximum flood level, will be 8,600 c.f.s., or the equivalent of 287 second-feet per square mile from the drainage area controlled. Owing to the good quality of the rock formation and the dissipating effect produced by the rock ravine at the discharge end, no damage to the dam is anticipated from the use of the spillway.

(7) Outlet.- A reinforced-concrete conduit, about 330 feet long, located in a rock cut on the right bank, will provide for stream control during the construction of the embankment and for reservoir control later. The cross-section will be a circular arch on short, vertical side walls, on a flat bottom, and will have an area of 37 square feet. Racks will be provided at the entrance to prevent stoppage by large debris. A reinforced-concrete stilling pool will return the discharge to the main stream below the dam without scour. The discharge capacity with pool at spillway elevation will be about 1400 second-feet. No gates will be provided, the reservoir being a retarding basin.

(8) Plan of construction.- It is proposed to build the outlet and a considerable part of the long embankment on the left terrace simultaneously. Then the stream will be diverted through the outlet, the embankment completed, and the spillway constructed. The upstream slope of the fill will be riprapped as the fill progresses. The time estimated for construction is about 8 months, or one construction season.

(9) Conservation storage.- Additional storage capacity of 6,400 acre-feet, or 4 inches of run-off, can be developed at this site by raising the spillway crest to Elevation 705, at an additional cost of $295,200, making the total cost of the development $1,029,000.

AYERS BROOK - NO. 30A

COST ESTIMATE

Item: No.:	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing and grubbing		Lump Sum	$ 3,000	
	Stream control		" "	4,000	
	Excavation, earth	63,000 c.y.	$0.40	25,200	
	Excavation, rock	50,000 c.y.	2.30	115,000	
	Backfill at structures	6,500 c.y.	0.60	3,900	
	Embankment, rolled fill	191,000 c.y.	0.40	76,400	
	Concrete, plain	2,500 c.y.	12.00	30,000	
	Concrete, reinforced	1,400 c.y.	12.00	16,800	
	Reinforcing steel	140,000 lbs.	0.06	8,400	
	Miscellaneous		Lump Sum	2,000	
				284,700	
	Contingencies		20%	57,300	
				342,000	
	Engineering and overhead		15%	51,000	
	Total				$392,000
2.	Relocation of Railroads and Utilities				
	Telephone lines	3-1/2 mi.	Lump Sum	1,500	
	Contingencies		10%	150	
				1,650	
	Engineering and overhead		10%	150	
	Total				1,800
3.	Rights of Way and Land				
	Land	1,040 ac.	Lump Sum	43,000	
	Buildings purchased	10 sets	" "	30,000	
				73,000	
	Legal, overhead, and general expense		20%	15,000	
	Total				88,000
4.	Highway Relocation				
	18-ft. tarvia state highway	3.5 mi.	Lump Sum	185,000	
	16-ft. gravel road	0.75 mi.	" "	22,500	
				207,500	
	Contingencies		10%	20,800	
				228,300	
	Engineering and overhead		10%	22,700	
	Total				251,000
5.	Grand Total Capital Cost				$733,800
6.	Total Annual Cost				$ 43,400

(11) South Tunbridge No. 49A.- (a) General.- South Tunbridge Reservoir, on the First Branch of the White River, Vermont, about 1-1/4 miles above the confluence with the White River, is outlined on Plate No. 88. The dam site is located about 1-1/2 miles north of South Royalton, Vermont, and the reservoir extends upstream about 4.5 miles to the Village of Tunbridge. The downstream one-third of the reservoir lies in the Town of Royalton, Windsor County, and the upstream two-thirds in the Town of Tunbridge, Orange County. The drainage area of 102 square miles is rugged terrain, with farm lands on the hillsides and in the valleys, and wooded hilltops. A number of small mill centers are along the main stream. As designed, the storage capacity is about 4.5 inches of run-off from the watershed above, or about 24,500 acre-feet. The flooded area at spillway crest, Elevation 553.0 m.s.l., is about 750 acres of which 400 acres are farm land and pasture of considerable value, and include about 15 sets of buildings. The remainder is wooded land. The Village of South Tunbridge, including about 25 sets of buildings and one cemetery of 200 graves, will be inundated.

(b) Highways and roads.- About 10 miles of roads will be flooded out. State Highway No. 110 will be relocated on the east side of the reservoir. This section will be macadam, 18 feet wide and 4.6 miles long. Three sections of local roads will be built of gravel and relocated on the west side of the reservoir. The total length of this type is 2.7 miles. Several bridges will be required. The tentative relocations are indicated on reservoir map Plate No. 88.

(c) Railroads.- No railroads will be involved.

(d) Other public works.- About 11 miles of telephone and transmission pole-line will require relocation.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geologic features are indicated on Plates Nos. 89 and 90.

(1) Geology.- The right abutment is a glacial outwash terrace underlain by a low rock hill, the summit of which lies about 25 feet below the terrace level. Metamorphic sedimentary rock outcrops on the slope of the terrace about 15 feet above river level, whence it dips beneath the flood plain of sand and silt to a depth of about 40 feet. It reaches the surface again on the left bank about 20 feet above the river, above which level it forms the left abutment.

(2) Available materials.- Abundant concrete aggregate and pervious material are available within 1/2 mile downstream on the right bank. Impervious material is available on the right bank 1/2 mile upstream.

(3) Dam and appurtenant parts.- A rolled-earth and rock dam is proposed, with a side-channel spillway cut into the rock of the left abutment. The dam will be 1,040 feet long. The top elevation will be 568.0 m.s.l., rising to a height of 88 feet above the stream bed. This will allow for a freeboard of 5 feet above the spillway-design flood.

(4) Alternate.- An alternate type of dam is a gravity concrete structure. The earth dam is submitted in this report because of its lower construction cost. The alternate dam would consist of a solid gravity spillway with non-overflow sections on either side, founded on ledge rock, with an earth section high on the right end. The outlets would consist of four conduits through the left non-overflow section, with butterfly and sleeve valves for control.

(5) Embankment.- The earth fill will be 25 feet wide on top. It will consist of an impervious core and rock covered pervious shoulders. The core will be keyed into the ground with a cut-off trench. Where ledge is at or near the surface, a concrete cut-off wall is substituted for the trench. Both the up and downstream faces of the

impervious core will be backed with pervious material, the outside of which will be heavy rock fill. The outside slopes will be 1 on 3 from bottom to within 15 feet of the top, the top 15 feet 1 on 2-1/2. Most of the rolled-earth material will be obtained from borrow pits within 1/4 mile distance, the rock fill to be spoil from the spillway excavation.

(6) Spillway.- A side channel spillway having a crest length of 320 feet, built into the ledge of the left abutment, will discharge into a concrete-lined channel 800 feet long. This channel will carry the flood water around the left end of the embankment, returning it to the river about 150 feet below the downstream toe of the dam. With a permanent crest at 553.0 m.s.l., the discharge capacity under a 10-foot surcharge (maximum flood-line) will be 39,500 second feet, or the equivalent of 387 second feet per square mile from the drainage area controlled. The freeboard of 5 feet will be above this 10-foot surcharge. The outflow from the spillway will be so directed into the river below that no damage is anticipated to the embankment from the spillway's use.

(7) Outlet.- A reinforced-concrete conduit constructed in the rock floor of the right bank will provide stream control during the construction of the embankment, and reservoir control later. The cross-section will be of spread horseshoe shape, and have an area of 167 square feet. The discharge capacity under the maximum operating head, spillway crest, will be 7,440 second feet. At the entrance, a gate section will be provided, which will include three 6.5 by 10-foot gates mechanically controlled from a gate house directly above. The gate house will be accessible by way of a concrete service bridge connecting with the top of the dam. A reinforced-concrete stilling basin will be provided at the discharge end to return the water to the river with a reduced velocity so as not to scour.

(8) Plan of construction.- It is proposed to construct first the outlet and gate house, including piers for the service bridge. The stream will then be diverted through the outlet and the embankment will be constructed simultaneously as the spillway channel is excavated. Finally the spillway weir will be constructed, the spillway channel lined with concrete, and the service bridge and control tower constructed. It is estimated that a construction period of about 10 months will be required, or one working season.

(9) Conservation storage.- Not feasible. To raise the spillway elevation will cause excessive property damage at the Village of Tunbridge.

(Table on following page)

SOUTH TUNBRIDGE - NO. 49A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing and grubbing		Lump Sum	$ 5,000	
	Stream control		" "	5,000	
	Excavation, earth	52,000 c.y.	$0.40	20,800	
	Excavation, rock	130,000 c.y.	2.00	260,000	
	Embankment, rolled fill	452,000 c.y.	0.35	158,200	
	Concrete, plain	8,800 c.y.	10.00	88,000	
	Concrete, reinforced	6,000 c.y.	12.00	72,000	
	Reinforcing steel	600,000 lbs.	0.06	36,000	
	Gates and machinery		Lump Sum	73,000	
	Gate house and miscellaneous		" "	10,000	
				728,000	
	Contingencies		20%	146,000	
				874,000	
	Engineering and overhead		15%	131,000	
	Total				$1,005,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission lines	11 mi.	Lump Sum	5,000	
	Contingencies		10%	500	
				5,500	
	Engineering and overhead		10%	500	
	Total				6,000
3.	Rights of Way and Land				
	Land	1,000 ac.	Lump Sum	80,000	
	Buildings purchased	40 sets	" "	159,000	
	Water rights		" "	10,000	
	Cemetery relocation	200 graves	" "	6,000	
				255,000	
	Legal, overhead, and general expense		20%	51,000	
	Total				306,000
4.	Highway Relocation				
	18-ft. tarvia state highway	4.6 mi.	Lump Sum	230,000	
	14-ft. gravel road	2.7 mi.	" "	146,400	
				376,400	
	Contingencies		10%	37,600	
				414,000	
	Engineering and overhead		10%	41,000	
	Total				455,000
5.	Grand Total Capital Cost				$1,772,000
6.	Total Annual Cost				$ 102,900

(12) North Hartland No. 63.- (a) General.- North Hartland Reservoir, on the Ottauquechee River, Vermont, about 1.8 miles above its junction with the Connecticut River, is outlined on Plate No. 91. The dam site is located about one mile northwest from North Hartland, Vermont, and the reservoir extends upstream about 4-1/2 miles, to the lower limits of the Village of Quechee. The lower part of the reservoir lies in the Town of Hartland, and the upper part in the Town of Hartford, all in Windsor County. The drainage area of 222 square miles is rugged with a number of mill centers along the main stream and in the lower reaches of the major tributaries. Some of the hillsides are farmed. As designed, the storage capacity will be about 4.1 inches of run-off from the watershed above, or about 48,500 acre-feet. The flooded area at the spillway crest, 528.0 m.s.l., will be about 900 acres, classified as follows:

(1) Agricultural land.....	400 acres of low value, including three sets of buildings.
(2) Pastureland...........	Included in (1) above.
(3) Wooded land...........	500 acres.
(4) Towns, etc.	No community centers below spillway elevation.

(b) Highways and roads.- None involved.

(c) Railroads.- No railroads involved.

(d) Other public works.- The dam proposed herein, will be located just above the site of an old dam now owned by the New England Power Association.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geologic features are indicated on Plates Nos. 92 and 93.

(f) Geology.- Bed rock occurs at shallow depths in the left abutment, in the river, and at depths of 45 to 65 feet in the right abutment. The overburden is fine sand and rock flour, which in the right abutment is compact and relatively impervious. The spillway and outlet tunnel will be excavated in fine-grained mica schist. Rock cover, above the tunnel roof, varies between 25 and 35 feet, the upper 10 to 15 feet being slightly broken.

(2) Available materials.- There is a scarcity of coarse materials suitable for hydraulic construction. The extensive fine sand and rock flour deposits near-by are suitable for use in an impervious, rolled-fill embankment. Spillway and tunnel excavation will supply abundant rock for rock-fill embankment. Coarse materials for construction of the pervious sections are available within one mile downstream. These deposits can also be used for concrete aggregate.

(3) Dam and appurtenant works.- A rolled earth and rock-fill earth dam across the main channel is proposed, with a concrete, side-channel spillway cut out of rock on the left bank. The total length is 1425 feet; the top elevation is 543.0 feet m.s.l., or about 153 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum flood elevation. In addition, an earth dike 700 feet long, with a maximum height 25 feet, top width 20 feet, at elevation 543.0, side slopes 1 on 3, is necessary on saddle in ridge west of main dam.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled earth and rock-fill embankment will be 30 feet wide on top. It is to consist of an impervious core from top to bottom, keyed into the ground with a concrete core wall about 7 feet deep along the axis of the dam; side slopes will be 1 on 1-1/2. The core is to be backed by a pervious section on both up and downstream faces, the outside slope of each to be 1 on 3 from the bottom to within 15 feet of the top, the top 15 feet to be 1 on 2-1/2. The outer layers of the upstream and downstream section will be built of heavy rock, with a rock-filled trench along the downstream toe to

provide for drainage. Little excavation will be required other than for the cut-off and for the toe trench, the ground preparation to consist principally of stripping of all vegetable matter. Materials from the spillway and tunnel excavation will be used together with borrow as needed.

(6) Spillway.- An open, concrete-weir type spillway, 645 feet long, will be provided on the left bank. The discharge will be carried around the end of the dam in a concrete-lined rock cut and returned to the river below. With the permanent crest at Elevation 528 feet m.s.l., the discharge capacity under a 10-foot head (the maximum flood-line) will be about 63,000 second-feet, or the equivalent of about 284 second-feet per square mile from the drainage area controlled. The freeboard of 5 feet will be above this 10-foot surcharge. No control will be provided. The spillway discharge will be far enough downstream from the toe of the dam and so guided with walls that any resulting scour will not reach the dam.

(7) Outlet.- A concrete-lined tunnel, excavated in rock, located in the left bank and having a cross-sectional area of 226 square feet, will provide for stream-control during the construction of the embankment and for reservoir-control later. Near the middle of the tunnel, a gate section will be provided, consisting of three openings, each to have a 7-1/2 by 12-foot gate mechanically operated from a gate house on top of the dam. Under the maximum operating head (spillway-crest) the outlet capacity will be about 11,100 second-feet. A reinforced concrete stilling basin will be provided.

(8) Plan of construction.- It is proposed first to construct the tunnel and stilling basin for stream-control and prepare the ground for the embankment; then, the spillway is to be excavated, using the spoil in the embankment. Finally, the embankment will be completed and the spillway-channel lined. The rock on the upstream and downstream faces

of the embankment is to be placed as the fill progresses. The time estimated for construction is about 16 months, or two construction seasons.

(9) Conservation storage.- Not feasible. Low-lying areas on the right bank of the reservoir and excessive property damage involved at Dewey's Mill by a higher spillway elevation make conservation storage impractical.

(Table on following page)

NORTH HARTLAND - NO. 63

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	350 ac.	Lump Sum $	30,500	
	Stream control		" "	20,500	
	Excavation, earth	309,000 c.y.	$0.40	123,600	
	Excavation, rock	321,000 c.y.	2.00	642,000	
	Excavation, tunnel and shaft	11,700 c.y.	10.00	117,000	
	Embankment, rolled fill	1632,000 c.y.	0.35	571,200	
	Concrete, plain	22,500 c.y.	10.00	225,000	
	Concrete, reinforced	7,500 c.y.	12.00	90,000	
	Reinforcing steel	680,000 lbs.	0.06	40,800	
	Gates and machinery		Lump Sum	84,000	
	Gate house and miscellaneous		" "	15,000	
				1,959,600	
	Contingencies		20%	391,400	
				2,351,000	
	Engineering and overhead		15%	353,000	
	Total				$2,704,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	1,420 ac.	Lump Sum	74,000	
	Buildings purchased	3 sets	" "	8,000	
	Water rights, developed		" "	30,000	
	Water rights, undeveloped		" "	20,000	
				132,000	
	Legal, overhead and general expense		20%	26,000	
	Total				158,000
4.	Highway Relocation				None
5.	Grand Total Capital Cost				$2,862,000
6.	Total Annual Cost				$ 156,200

(13) <u>Claremont - No. 64A.</u>- (a) <u>General.</u>- The Claremont Reservoir, on Sugar River, New Hampshire, about 6.7 miles above its junction with the Connecticut River, is outlined on Plate No. 97. The dam site is located about one mile southeast from Claremont, New Hampshire; and the reservoir extends upstream about 5 miles, lying for the most part in the Town of Claremont, a small portion lying in the Town of Newport, all in Sullivan County. The 245 square miles of drainage area is hilly with a few sharp peaks. At the headwaters, a number of ponds are found. Considerable farming is done on the hillsides and along the valley. As designed, the storage capacity would provide for about 4.6 inches of run-off from the drainage area or about 60,000 acre-feet between the empty reservoir and spillway crest. The flooded area at the spillway crest (607.0 m.s.l.) would be about 1,370 acres, classified as follows:

(1) Agricultural land..... 600 acres of considerable value, including 40 sets of buildings.

(2) Pastureland........... 700 acres.

(3) Wooded land........... 100 acres.

(4) Towns, etc. .... small community of Puckershire.

(b) <u>Highways and roads.</u>- About 1-1/2 miles of first-class, concrete-slab type, state highway and 10 miles of secondary roads would be flooded. It is proposed to relocate the first-class highway over the high ground to the north of the reservoir, the new location being about 1.9 miles, as indicated on the reservoir map, Plate No. 97. A secondary road, part gravel and part bituminous macadam is proposed, to skirt the lower half of the reservoir along the left edge; also a connecting link across the valley just above the reservoir;

the total length of secondary road, as tentatively indicated on the reservoir map, would be about 6 miles, including one bridge across Sugar River.

(c) Railroads.- About three miles of single-track railroad, a branch line of the Boston and Maine Railroad, will require relocation. The tentative plan is sketched on the reservoir map, Plate No. 97.

(d) Other public works.- About 8 miles of telephone and transmission pole-line will require relocation.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geologic features are indicated on Plates Nos. 98 and 99.

(1) Geology.- A low hill, rising about 70 feet above pool level, forms the right abutment. Mica schist, overlain by sand, rock flour, gravel, and boulders, lies over 100 feet beneath the summit of this hill. Rock is located under the flood plain which is 1,200 feet wide, at a depth of about 120 feet below the river. From this low point in the floor, rock rises in a hill forming the left abutment, where it is overlain by sand, rock flour and some gravel. A major portion of the valley overburden consists of thick deposits of slate-gray rock flour or glacial silt overlain by about 18 feet of fine and medium to coarse sand, and gravel. The spillway and outlet conduit will be constructed on rock in the left abutment.

(2) Available materials.- Extensive deposits of fine-grained materials, suitable for an impervious section are available on the hillside adjacent to the left abutment. A large volume of rock from excavations will be available for rock-fill embankment. Sand and gravel deposits occur in the valley bottom, within 0.5 mile upstream and downstream. These may be used for supplementary pervious

embankment and as concrete aggregate.

(3) Dam and appurtenant works.- A rolled-earth fill is proposed, across the main stream, with a side channel spillway cut into the left bank about 100 feet beyond the dam. The length of the earth fill will be about 2,120 feet; the top elevation will be 625.0 m.s.l. rising to a height of 105 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum flood level after an assumed settlement of 3 feet of the rock flour deposit. This deposit has been tested for consolidation and shear in the Soils Laboratory. It was found adequately able to take any load imposed by the dam, but a consolidation of the foundation material of 2.3 feet over a long period of time may be expected.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The earth-fill will be 25 feet wide on top. It will consist of an impervious core from top to bottom keyed into the ground with a cut-off section along the axis of the embankment. The impervious core will be backed by a pervious section on both the upstream and downstream faces, with outside slopes of 1 on 3 from the bottom to within 15 feet of the top; the top 15 feet to be 1 on 2-1/2. A rock-filled trench will be constructed along the downstream toe to provide for drainage. Materials for the embankment will be obtained from borrow pits for the most part; spoil from the spillway excavation will be utilized where adaptable.

(6) Spillway.- A concrete spillway weir, 520 feet long, will be constructed in the rock ledge on the left bank about 100 feet from the dam. The spillway channel will carry the flood discharge around the dam and spill into the river about 800 feet below the dam. With the crest at 607.0 m.s.l., the discharge capacity under a 10-foot surcharge (maximum flood level) will be 50,600 c.f.s. or the

equivalent of 207 second-feet per square mile from the watershed controlled. The freeboard of 8 feet for the embankment as constructed or 5 feet after settlement will be above the 10-foot surcharge. Owing to the distant location of the spillway from the dam and the considerable distances below, at which the discharge returns to the river, no effect on the dam is anticipated from use of the spillway.

(7) Outlet.- The outlet will consist of a reinforced concrete conduit constructed through a rock cut in the left bank. It will provide for stream-control during the construction of the embankment and for reservoir-control later. The cross-sectional area will be 238 square feet and the capacity with pool at spillway elevation will be about 12,300 second feet. At the entrance of the conduit a gate section will be provided, consisting of three 8 x 12 feet service gates and one emergency gate, all to be mechanically operated from a gate house immediately above. The gate house will be accessible by way of a steel truss service bridge connecting with the top of the dam. A reinforced concrete stilling basin will be provided at the discharge end, returning the water to the river channel well below the toe of the embankment.

(8) Plan of construction.- It is proposed to first construct the outlet and gate house, the stream will then be diverted through the conduit and the earth embankment built simultaneously with the spillway excavation leaving an opening at the existing river channel for flood discharge during the major part of the construction period. The estimated time for construction is about 30 months or 3 construction seasons.

(9) Conservation storage.- Not feasible. Power benefits are low and the cost of increasing storage capacity is high on account of the long dam, expensive property, and extensive railroad and highway relocation involved.

CLAREMONT - NO. 64A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	140 ac.	Lump Sum	$ 17,000	
	Stream control		" "	12,000	
	Excavation, earth	297,000 cy	$0.40	118,800	
	Excavation, rock	280,000 cy	2.00	560,000	
	Embankment, rolled-fill	1,746,000 cy	0.35	611,100	
	Concrete, plain	22,700 cy	10.00	227,000	
	Concrete, reinforced	10,200 cy	12.00	122,400	
	Reinforcing steel	1,200,000 lbs.	0.06	72,000	
	Structural steel, service bridge	100,000 lbs.	0.10	10,000	
	Gates and machinery		Lump Sum	88,000	
	Gate house and miscellaneous		" "	25,000	
				1,863,300	
	Contingencies		20%	372,700	
				2,236,000	
	Engineering and overhead		15%	335,000	
	Total				$2,571,000
2.	Relocation of Railroads and Utilities				
	Single-track railroad, branch line	3 mi.	Lump Sum	507,200	
	Telephone lines	8 mi.	" "	4,000	
				511,200	
	Contingencies		10%	51,100	
				562,300	
	Engineering and overhead		10%	56,700	
	Total				619,000
3.	Rights of way and Land				
	Land	2,000 ac.	Lump Sum	100,000	
	Buildings purchased	60 sets	" "	200,000	
				300,000	
	Legal, overhead, and general expense		20%	60,000	
	Total				360,000
4.	Highway Relocation				
	16-ft. gravel road, bridge	3.2 mi.	Lump Sum	169,000	
	20-ft. tarvia state highway	2.3 mi.	" "	115,000	
	20-ft. concrete state highway	1.9 mi.	" "	152,000	
				436,000	
	Contingencies		10%	44,000	
				480,000	
	Engineering and overhead		10%	48,000	
	Total				528,000
5.	Grand Total Capital Cost				$4,078,000
6.	Total Annual Cost				$227,200

(14) North Springfield - No. 55A.- (a) General.- North Springfield Reservoir, on the Black River, Vermont, about 8-1/4 miles above its junction with the Connecticut, is outlined on Plate No. 103. The dam site is located about one mile northeast of North Springfield, Vermont; and the reservoir extends upstream about 4-1/2 miles, lying in the Towns of Weathersfield and Springfield, Windsor County. The drainage area of 156 square miles is mostly rugged hill-land; the hilltops are wooded and pasture farm-lands extend up the lower reaches of the small valleys. As proposed, the storage capacity would provide for about 3.2 inches of run-off from this watershed, or about 26,500 acre-feet. The flooded area, up to the spillway crest, would be about 835 acres, classified as follows:

(1)	Agricultural land	700 acres of average to high value, includes 30 sets of buildings.
(2)	Pastureland	Included in (1) above.
(3)	Wooded land	135 acres.
(4)	Towns, etc.	One cemetery, consisting of 150 graves, to be relocated. A small section of the community of Perkinsville will be inundated.

(b) Highways and roads.- About six or eight miles of secondary highways (including several bridges) criss-crossing the reservoir, would be flooded, but it is not believed that there would be further need of these many local connecting links upon the conversion of the area to reservoir use. It is proposed to make one connecting link across the upper end of the reservoir; it will be about 0.6 mile long, including one bridge. The tentative location is indicated on the reservoir map, Plate No. 103.

(c) Railroads.- No railroads are involved.

(d) Other public works.- About eight miles of telephone and transmission pole-line will be relocated.

(e) Dam.- A general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 104 and 105.

(1) Geology.- Granite gneiss forms the lower part of the right abutment. The rock surface rises from river level to a point about 45 feet above the stream, where it dips gently north. On the left side, it dips beneath the abutment and at boring #1 lies about 30 feet below river level. Pervious sands and coarse gravels lie above the rock in this abutment. These grade upstream into more impervious fine-grained material.

(2) Available materials.- Material for impervious embankment is available 0.5 mile upstream, under an overlay of sand and gravel. Concrete aggregate may be obtained from sand and gravel bars upstream, along the right bank, or from the coarse overlay mentioned. Any deficiency in rock for toe and shoulder construction may be supplemented by rock quarried from the hill about 0.5 mile east.

(3) Dam and appurtenant works.- The dam will consist of a rolled earth-fill, extending from the left natural abutment across the main channel to a concrete abutment wall on the immediate right bank; an outlet-control section will adjoin the concrete wall and will continue in an overflow concrete gravity section spillway closing the right side. The total length of the dam will be about 1100 feet, 600 feet being earth-fill. The top of the earth-fill will be at 532.5 m.s.l., or about 83 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-fill embankment will be 20 feet wide on top. It will consist of an impervious core from top to bottom, keyed into the ground with a steel sheet pile cut-off along the axis of the dam. The impervious core will be backed with a pervious section on both faces with an outside slope of 1 on 3 from the bottom to within 15 feet of the top; the top 15 feet to be 1 on 2-1/2. A rock-filled trench at the downstream toe will provide drainage. To protect against scour from spillway overflow, the downstream toe will be constructed of heavy rock fill. Materials will be obtained from borrow pits; the spoil from the excavation will be used where adaptable.

(6) Spillway.- A 398-foot-long, ogee section, concrete spillway will provide for flood discharge to the right of the embankment. With a permanent crest at Elevation 519.0 m.s.l., the discharge capacity under a surcharge of 8.5 feet (the spillway-design flood) will be about 39,000 second-feet, or the equivalent of 250 second-feet per square mile from the watershed above. The freeboard of 5 feet will be above the 8.5 surcharge. A wide excavation below the spillway, together with the heavy rock-fill at the toe of the embankment, is believed adequate to prevent damage during spillway discharge.

(7) Outlet.- Three outlet conduits are to be provided through the gate-section of the dam. The approach channel, about 800 feet long, will be in ledge on the right bank. Each of the conduits will be provided with 7-1/2 by 10-foot gates, mechanically operated from a gate house above, at the axis of the dam. The total discharge capacity with the pool at spillway crest will be about 13,150 c.f.s. The discharge will be quieted in a stilling pool, and returned to the river about 500 feet below the downstream toe of the

embankment.

(8) Plan of construction.- It is proposed first to construct the outlet section and part of the embankment on the left bank simultaneously. After the outlet is completed, the river will be diverted through it, and the remainder of the earth-fill constructed simultaneously with the spillway excavation. Finally, the concrete spillway will be placed. The upstream slope of the embankment will be riprapped as the fill progresses. The estimated time required for construction is about eight months, or one construction season.

(9) Conservation storage.- Not feasible. Low-lying areas at or near the dam site make a higher spillway elevation undesirable as well as expensive.

(Table on following page)

NORTH SPRINGFIELD - NO. 55A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	100 ac.	Lump Sum	$ 10,000	
	Stream control		" "	5,000	
	Excavation, earth	324,000 cy	$0.40	129,600	
	Excavation, rock	23,000 cy	2.30	52,900	
	Embankment, rolled-fill	360,000 cy	0.35	126,000	
	Riprap, dumped	11,600 cy	1.50	17,400	
	Riprap, hand-placed	7,700 cy	3.00	23,100	
	Sheet piling (cut-off)	28,800 sq.ft.	1.25	36,000	
	Concrete, plain	21,000 cy	10.00	210,000	
	Concrete, reinforced	4,100 cy	12.00	49,200	
	Reinforcing steel	410,000 lbs.	0.06	24,600	
	Gates and machinery		Lump Sum	67,000	
	Gate house and miscellaneous		" "	15,000	
				765,800	
	Contingencies		20%	153,200	
				919,000	
	Engineering and overhead		15%	138,000	
	Total				$1,057,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission lines	8 mi.	Lump Sum	3,500	
	Contingencies		10%	350	
				3,850	
	Engineering and overhead		10%	350	
	Total				4,200
3.	Rights of Way and Land				
	Land	900 ac.	Lump Sum	34,000	
	Buildings purchased	30 sets	" "	65,000	
	Water rights		" "	22,000	
	Cemetery relocation	150 graves	" "	4,000	
				125,000	
	Legal, overhead, and general expense		20%	25,000	
	Total				150,000
4.	Highway Relocation				
	14-ft. gravel road, bridge	0.60 mi.	Lump Sum	57,700	
	Contingencies		10%	5,800	
				63,500	
	Engineering and overhead		10%	6,500	
	Total				70,000
5.	Grand Total Capital Cost				$1,281,200
6.	Total Annual Cost				$73,000

(15) Newfane - No. 40A.- (a) General.- Newfane Reservoir, on the West River, about 10.8 miles above its junction with the Connecticut, is outlined on Plate No. 106. The dam site is located about one mile southeast of Newfane, Vermont, and the reservoir extends upstream about 10-1/2 miles, lying in the Towns of Newfane and Townshend, Windham County. The 326 square miles of drainage area is hilly to mountainous, rugged along the main stream and to the northeast with a few mill centers to be found along the main channel and in the lower reaches of the larger tributaries; at the headwaters and to the southeast the hills are more gentle, the area consisting mostly of farm lands embracing a few small village centers. As proposed, the storage capacity would provide for 6.0 inches of run-off from the watershed above, or 105,000 acre-feet between the spillway crest and empty reservoir. The area flooded, to the spillway crest (486.0 m.s.l.), would be 2,130 acres classified as follows:

(1) Agricultural land ..... 1500 acres of considerable value, including about 30 sets of buildings.

(2) Pastureland .... Included in (1) above.

(3) Wooded land .... 500 acres.

(4) Towns, etc. .... The Village of Harmonyville, including about 30 sets of buildings; and one cemetery consisting of 350 graves.

(b) Highways and roads.- About 3.3 miles of bituminous type state highway and 7.7 miles of gravel road will be relocated. The estimate of cost of highway relocation considers reproducing highway facilities of a character equivalent to those now existing. It is understood that the estimated cost of relocation calculated by the State of Vermont includes an additional reservoir crossing to afford access to a state forest. Considering that access to a state forest is a remote contingency during flood season and any excessive flooding would be temporary in the upper reaches of the reservoir, the cost of the additional structure was not included in the Government estimate. A tentative relocation is sketched on the reservoir map, Plate No. 106.

(c) Railroads.- About 8 miles of old, abandoned railroad would be flooded out. There is little value in what remains; no charge for this railroad has been considered in the reservoir costs.

(d) Other public works.- About 16 miles of telephone line will be relocated.

(e) Dam.- The general design, the area and capacity curves, and the geological features are indicated on Plates Nos. 107 and 108.

(1) Geology.- Rock is exposed at intervals on the right bank, from the water surface to above the top of the proposed dam; rock on the left bank is deeply buried, and does not appear at the surface below Elevation 550. At the lowest point, the underlying rock valley is 40 feet below the water surface. Throughout the flood-plain section, the overburden is from 56 to 67 feet thick. Deposits below the water table are of glacial origin, consisting largely of uniform fine and medium sand. On the left bank the overburden consists of stratified sand and gravel in the upper portion, and a compact mixture of sand, silt, gravel, and boulders in the lower. The spillway and tunnel will be constructed in a hard crystalline formation of steeply inclined beds of mica and hornblende schist.

(2) Available materials.- Rock obtained from the excavations may be used as rock fill in the embankment. The principal borrow area is located on the left side, where the overburden contains both fine and coarse materials suitable for hydraulic construction. Additional borrow is available on the right side, within 1/2 mile of the

site. Gravel banks for concrete aggregates are located on the right side within 1/2 mile. The hydraulic-fill materials are to be sluiced from a hog-box, ground sluicing being impractical because of the thin overburden and frequent ledge exposure.

(3) Dam and appurtenant works.- A hydraulic-fill earth dam across the main channel, with a concrete-lined, side-channel spillway, in solid rock on the right bank, is proposed. The overall length is 2,530 feet, 1,850 feet being earth fill. The top elevation is 501.0 m.s.l., or about 131 feet above the stream bed. This will allow for a freeboard of 5 feet above the spillway-design flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The earth fill will be 30 feet wide on top. With side slopes of 1 on 3 as a minimum for the lower section, to 15 feet of the top of the proposed dam, the top 15 feet will be 1 on 2-1/2. A cut-off along the axis of the dam and a rock-filled trench along the downstream toe will be provided. For the most part, the construction will be hydraulic-fill, the material being sluiced from a "hog-box". The hydraulic fill will be carried to as high an elevation as practicable. The embankment will be completed by a rolled-fill. The fill material will come from borrow pits within a one-half-mile distance. A blanket of impervious material will extend 500 feet upstream from the upper toe of the embankment, and the upstream face of the embankment will be paved with rock.

(6) Spillway.- An open, side channel spillway, 700 feet long, is to be provided on the right bank. The discharge will be carried around the end of the dam in a concrete-lined channel through rock and returned to the river below the stilling pool of the outlet. With the spillway crest at Elevation 486.0 m.s.l., the discharge

capacity under a 10-foot head (the spillway-design flood) will be about 69,000 second-feet, or the equivalent of about 210 second-feet per square mile from the drainage area behind the dam. The freeboard of 5 feet will be above the 10-foot surcharge. The discharge end will extend sufficiently downstream from the toe of the dam that resulting scour will not affect the dam.

(7) Outlet.- The outlet will be a concrete-lined tunnel excavated in solid rock on the right bank. It will be 1020 feet in length and have a net cross-sectional area of 212 square feet. It will be of a horseshoe shape. The outlet will provide for stream-control during the construction of the embankment as well as for reservoir-control later. The discharge capacity under maximum head (spillway elevation) will be about 12,000 second-feet. The control will consist of a gate section comprising three gates, operated from a control tower located near the center line of the dam, at about the mid-point of the tunnel. At the discharge end a reinforced concrete stilling basin will be built on rock foundation.

(8) Plan of construction.- It is proposed to construct a portion of the fill simultaneously with construction of the outlet; the exposed end of the fill to be protected by a layer of impervious material built with an outside slope of 1 on 2 and paved with riprap to a sufficient height to guard against scour and ice runs in the river, which will be left open during the winter and spring flood season. Upon completion of the outlet tunnel the stream will be diverted through the tunnel and the remaining portion of the embankment built as the excavation for the spillway progresses. Finally, the embankment will be completed, the stilling basin built, and the spillway lined with concrete. The time estimated for construction is about 16 months or two construction seasons.

(9) Penstocks.- The necessary penstock and outlet facilities for a power development at the site in the future can be made as economically when the power installation is to be constructed as they can be made now. The needed facilities for unwatering the pond will be provided by the flood control outlet, and are therefore provided without additional cost at this time.

(10) Conservation storage.- Conservation storage at this site is justifiable and 118,200 acre-feet, equivalent to 6.8 inches of run-off will raise the spillway to Elevation 530 m.s.l. The cost of providing this additional storage is $2,556,500, making the total cost for this development $7,080,000.

(Table on following page.)

NEWFANE - NO. 40A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	300 ac.	Lump Sum	$24,000	
	Stream control		" "	16,000	
	Excavation, earth	270,000 cy	$0.40	108,000	
	Excavation, rock	362,000 cy	2.00	724,000	
	Excavation, tunnel and shaft	18,000 cy	10.00	180,000	
	Embankment, hydraulic fill	2,224,000 cy	0.35	778,400	
	Concrete, plain	20,200 cy	10.00	202,000	
	Concrete, reinforced	12,000 cy	12.00	144,000	
	Reinforcing steel	1,200,000 lbs.	0.06	72,000	
	Gates and machinery		Lump Sum	84,000	
	Gate house and miscellaneous		Lump Sum	15,000	
				2,347,400	
	Contingencies		20%	469,600	
				2,817,000	
	Engineering and overhead		15%	423,000	
	Total				$3,240,000
2.	Relocation of Railroads and Utilities				
	Telephone lines	16 mi.	Lump Sum	7,000	
	Contingencies		10%	700	
				7,700	
	Engineering and overhead-		10%	800	
	Total				8,500
3.	Rights of Way and Land				
	Land	2,000 ac.	Lump Sum	80,000	
	Buildings purchased	60 sets	" "	240,000	
	Cemetery relocation	350 graves	" "	10,000	
				330,000	
	Legal, overhead and general expense		20%	66,000	
	Total				396,000
4.	Highway Relocation				
	14-ft. gravel road, bridge	4.1 mi.	Lump Sum	174,500	
	20-ft. tarvia highway, reservoir crossing	3.3 mi.	" "	381,500	
	20-ft. gravel highway	3.6 mi.	" "	162,000	
				718,000	
	Contingencies		10%	72,000	
				790,000	
	Engineering and overhead		10%	79,000	
	Total				869,000
5.	Grand Total Capital Cost				$4,513,500
6.	Total Annual Cost				250,900

(16) Surry Mountain - No. 57A.- (a) General.- Surry Mountain Reservoir, on the Ashuelot River, about 34.6 miles above its junction with the Connecticut, is outlined on Plate No. 109. The dam site is located about five miles northwest from Keene, New Hampshire, and the reservoir extends four miles upstream, all lying in the Town of Surry, in Cheshire County. The 100 square miles of drainage area controlled is hilly to mountainous. At the headwaters the hills flatten out, embracing a number of scattered ponds. The hilltops are mostly wooded, but the hillsides and valleys are farmed. A few small mill centers are found along the main stream. As designed, storage capacity would provide for about 6.0-inch run-off from the watershed, or 32,000 acre-feet between the spillway crest and empty reservoir. The flood area to the spillway crest (541.0 m.s.l.) would be about 1,150 acres, classified as follows:

(1) Agricultural land ..... 800 acres of considerable value, including about 8 sets of buildings.

(2) Pastureland .... Included in (1) above.

(3) Wooded land .... 350 acres.

(4) Towns, etc. .... A small part, along the north limits, of the Village of Surry.

(b) Highways and roads.- About nine-tenths mile of 18-foot bituminous macadam state highway would be flooded out. It is proposed to raise this portion of the highway and resurface it with 18-foot bituminous macadam. About three-tenths mile of 18-foot bituminous macadam road relocation will be necessary to carry the road around the spillway structure at the west end of the dam. In all, then, 1.2 miles must be raised or rebuilt.

(c) Railroads.- No railroads are involved.

(d) Other public works.- About 1.2 miles of telephone pole-line will need to be relocated, and about three miles of steel-tower transmission line.

(e) Dam.- The general design, the area and capacity curves, and the geologic features are indicated on Plates Nos. 110 and 111.

(1) Geology.- In the right abutment, granite rises high above spillway elevation, under a shallow cover of sand and soil. The rock surface dips east beneath the river flood-plain to a depth of about 95 feet below river level. It rises again in the left abutment under an overburden of gravel, sand, and boulders, approximately 100 feet thick. Interstratified deposits of rock flour and fine sand occur in the foundation overburden from about river level to about 50 feet below. These deposits under the base of the hill forming the left abutment are more compact, and more variable, containing much rock flour, sand, some gravel and boulders. The spillway and outlet conduit will be excavated in granite in the right abutment.

(2) Available materials.- Gravel and sand for hydraulic construction are available nearby in the hill on the left side. They will be transported to and sluiced from a sluice or hog-box. Concrete aggregate may be obtained from deposits on the left side within 0.5 mile. Granite from excavations for spillway and conduit will be used for rock fill and its quality is such as to make it desirable as supplementary coarse aggregate.

(3) Dam and appurtenant works.- A hydraulic-filled earth and rock dam across the main channel, with a concrete side-channel spillway on the right bank, is proposed. The total length of earth fill is about 1,630 feet. The top elevation is 556.0 m.s.l., or about 76 feet above the stream bed. This will allow for a freeboard of 5 feet above

the maximum flood line.

(4) Alternate.- No alternative plan is proposed.

(5) Embankment.- The earth fill will be 30 feet wide on top. It is to consist of an impervious core from top to bottom, keyed into the ground with a cut-off section 10 to 20 feet deep along the axis of the dam, the 20-foot depth being for 600 feet on the left bank, and where the pervious overburden is deep. The side slopes of the impervious core will be approximately 1 on 1-1/2. The core will be backed by a pervious section on both up and downstream faces, the outside slope of each to be 1 on 3 from bottom to within 15 feet of the top; the top 15 feet will have slopes of 1 on 2-1/2. A rock-filled trench along the downstream toe will provide drainage. The materials obtained from spoil excavation will be used as far as possible; the balance will be obtained from borrow pits.

(6) Spillway.- An open spillway, over a low concrete weir 305 feet long, will carry the flood waters around the embankment, discharging them at a point about 200 feet below the downstream toe. With the permanent crest at Elevation 541.0 m.s.l., the discharge capacity under a 10-foot surcharge will be about 30,000 c.f.s., or the equivalent of 300 second-feet per square mile from the watershed controlled. The 5-foot freeboard will be above the 10-foot surcharge.

(7) Outlet.- A reinforced concrete conduit 480 feet long will provide for stream-control during the construction of the embankment and for reservoir-control later. The cross-section will be of a horseshoe shape, having an area of 120 square feet. The capacity under maximum operating head (spillway crest) will be approximately 5,000 c.f.s. A reinforced concrete stilling basin will be provided, from which the water will be carried in open channel, discharging into the natural stream channel at a point 450 feet beyond the downstream toe of the dam. A

gate section will be provided at the upstream end of the conduit. The control will consist of two 7 by 10-foot gates, mechanically operated from a gate house above, approached by a service bridge from the top of the embankment.

(8) Plan of construction.- It is proposed to construct the outlet during the first construction season and prepare the ground for the earth fill. The stream will then be diverted through the outlet, and the embankment built simultaneously with the spillway. The estimated time for construction is 16 months or two working seasons.

(9) Conservation storage.- Not feasible. Potential power benefits are low and only a slight increase in storage is possible at this site without flooding the Village of Surry at a prohibitive cost.

(Table on following page.)

SURRY MOUNTAIN - NO. 57A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	150 ac.	Lump Sum	$16,000	
	Stream Control		" "	8,000	
	Excavation, earth	132,000 c.y.	$0.40	52,800	
	Excavation, rock	133,000 c.y.	2.00	266,000	
	Embankment, hydraulic fill	788,000 c.y.	0.40	315,200	
	Concrete, plain	10,300 c.y.	10.00	103,000	
	Concrete, reinforced	5,000 c.y.	12.00	60,000	
	Reinforcing steel	530,000 lbs.	0.06	31,800	
	Gates and machinery		Lump Sum	71,000	
	Gate house and miscellaneous		" "	15,000	
				938,800	
	Contingencies		20%	187,200	
				1,126,000	
	Engineering and overhead		15%	169,000	
	Total				$1,295,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission pole lines	1.2 mi.	Lump Sum	1,500	
	Steel tower transmission line	.3 mi.	Lump Sum	30,000	
				31,500	
	Contingencies		10%	3,100	
				34,600	
	Engineering and overhead		10%	3,500	
	Total				38,100
3.	Rights of Way and Land				
	Land	1300 ac.	Lump Sum	95,000	
	Buildings purchased	20 sets	" "	63,000	
				158,000	
	Legal, overhead and general expense		20%	32,000	
	Total				190,000
4.	Highway Relocation				
	18-ft. Bit. Mac. State Highway 1.2 mi.		Lump Sum	80,000	
	Contingencies		10%	8,000	
				88,000	
	Engineering and overhead		10%	9,000	
	Total				97,000
5.	Grand Total Capital Cost				$1,620,100
6.	Total Annual Cost				$ 94,900

(17) Lower Naukeag - No. 59.- (a) General.- Lower Naukeag Reservoir is outlined on Plate No. 112. The dam site is located on Millers River, 41.7 miles above the junction of the Millers and Connecticut Rivers, about 1.5 miles north of North Ashburnham station, and about 0.1 mile above a bridge across Millers River. The reservoir consists of two branches, of which one branch extends 1.75 miles upstream along the Millers River, and another branch, including Lower Naukeag Lake, extends about two miles upstream from the dam site; a gully deepened by excavation connects the two branches, and will provide drainage for Lower Naukeag Lake. Water rights of the existing development are vested in the Winchendon Electric Light and Power Co. The reservoir is located in the Township of Ashburnham, Worcester County, Massachusetts. The drainage area of 19.7 square miles is mostly hilly, covered with second-growth timber and brush of little value. As proposed, the storage capacity will provide for about 5.1 inches of run-off from this watershed, or about 5,400 acre-feet. The flooded area to the spillway crest will be about 650 acres, which includes 250 acres in the existing lake, classified as follows:

(1) Agricultural land ..... None

(2) Pastureland .... 30 acres

(3) Wooded land .... 360 acres

(4) Towns, etc. .... No towns are within the area. Three sets of farm buildings and about 43 cottages, scattered on the shores of Lower Naukeag Lake, will be inundated.

(b) Highways and roads.- A local road will be relocated around the dam and reservoir for a distance of one mile. A total length of about 2 miles of local road will be improved. The type will be gravel

14 feet wide.

(c) Railroads.- No railroads are located within the area.

(d) Other public works.- The existing low dam, now owned by Winchendon Electric Light and Power Co., must be acquired.

(e) Dam.- A general design of the dam and dikes, the area and capacity curves, and the geological features are indicated on Plates Nos. 113 and 114.

(1) Geology.- At the dam, granite gneiss occurs on the left bank to a height of about 5 feet above the river. The rock surface dips slightly toward the west beneath an overburden composed of sand and rock flour, together with some gravel. The rock floor at the Sherberts Mill dike site is situated at an uncertain depth beneath a relatively impervious formation of sand and rock-flour and boulders. A rolled-fill earth dam and two dike embankments are proposed, with spillway structure and outlet conduit constructed on rock at the river.

(2) Available materials.- Materials for the impervious rolled-fill sections, at both the dam and nearby Sherberts Mill dike, may be obtained upstream within 0.25 mile. Sand and gravel for pervious embankment construction and for concrete aggregate is available downstream within 0.5 mile. Materials similar to those named above are available near the Pole Street dike site for both pervious and impervious embankment. A portion of the rock fill required for riprap may be obtained from rock excavations and boulders. Supplementary rock fill may be obtained from quarry stone.

(3) Dam and appurtenant works.- The dam and dikes will consist of rolled earth-fill. The dam across Millers River contains the spillway and conduit. The total length of this dam will be 470 feet, the earth fill being 270 feet, the outlet section 20 feet, and

the concrete spillway 180 feet. The present outlet of Lower Naukeag Lake will be blocked by a dike at Sherberts Mill, about 2,000 feet south of the Millers River dam. The maximum height of the dike is 41 feet and the length 800 feet. The low ground west of Lower Naukeag Lake will be protected by a dike which starts at a point about 3,000 feet southeast of Sherberts Mill and follows Pole Street in a southeasterly direction for a distance of about 4,800 feet. The maximum height of this dike is 15 feet and the average 8.5 feet. The top elevation of dam and dikes is 1,084 m.s.l., or about 30 feet above the stream-bed elevation at the Millers River dam. This will allow a freeboard of 4 feet above maximum flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-fill earth embankment of the main dam and Sherberts Mill dike will be 20 feet wide on top. The embankments will consist of an impervious core from top to bottom, with the sides sloping 1 on 1-1/4, keyed into the ground with a cut-off section along the axis of the dam. The impervious core will be backed with a pervious section on both faces, the outside slope of which will be 1 on 3 from the bottom to within 15 feet of the top, and 1 on 2-1/2 for the remaining 15 feet for the upstream side and 1 on 4 from the bottom to within 15 feet of the top, and 1 on 3 for the remaining 15 feet for the downstream side. The upstream slope will be riprapped with 1-1/2 feet of hand-placed stone. The material for the embankments will be obtained from borrow. The Pole Street dike is similar in section to the Sherberts Mill dike, except that no cut-off is provided and the downstream side is sloped 1 on 4 from top to bottom.

(6) Spillway.- A 180-foot spillway weir will be constructed in the dam across Millers River. With the crest at elevation

1,076 m.s.l. and a 4-foot surcharge, the discharge capacity will be 4,920 c.f.s., or about 250 second-feet per square mile from the watershed controlled. The outlet will be constructed adjacent to the spillway, and concrete abutment walls separate the spillway and outlet sections from the earth sections. During spillway operation, the water is turned loose immediately after leaving the spillway weir without damage to the embankment.

(7) Outlet.- The outlet consists of an approach channel and a discharge channel, with a concrete gate section 20 feet long at the right end of the spillway weir. The discharge capacity under the maximum operating head (spillway crest) will be 1,315 second-feet. The gate section will be provided with two 3.5 by 7-foot cast-steel sluice gates, hand-operated from a gate house directly above. Trash racks will be provided over the gate openings. A reinforced concrete stilling basin will be constructed at the discharge end, returning the water to the river with less than scouring velocity.

(8) Plan of construction.- It is proposed first to construct the outlet, including the abutments and spillway weir, at Millers River dam, and prepare the ground for the embankment. The stream will then be diverted through the outlet and the embankment completed. Lower Naukeag Lake may be lowered before construction of Sherberts Mill dike, and the present gate at the outlet of the lake kept closed long enough to construct the bottom part of the dike. The outlet of the lake will then be diverted through the gully to Millers River and the embankment completed. Pole Street dike may be constructed simultaneously with other work. It is estimated that a construction period of eight months, or one working season, will be required.

(9) Conservation storage.- Not feasible. The cost of increasing the height of the long dikes will be prohibitive.

LOWER NAUKEAG - NO. 59

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	240 ac.	Lump Sum	$ 18,000	
	Stream control		" "	2,000	
	Excavation, earth	45,400 c.y.	$0.40	18,160	
	Excavation, rock	1,800 c.y.	3.00	5,400	
	Embankment, rolled-fill	147,000 c.y.	0.60	88,200	
	Riprap, hand placed	9,500 c.y.	3.00	28,500	
	Concrete, plain	4,300 c.y.	10.00	43,000	
	Concrete, reinforced	300 c.y.	12.00	3,600	
	Reinforcing steel	30,000 lbs.	0.06	1,800	
	Gates and machinery		Lump Sum	5,000	
	Miscellaneous		" "	2,000	
				215,660	
	Contingencies		20%	43,340	
				259,000	
	Engineering and overhead		15%	39,000	
	Total				$ 298,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	700 ac.	Lump Sum	7,000	
	Cottages, summer resort property		" "	57,000	
	Water rights		" "	5,000	
				69,000	
	Legal, overhead and general expense		20%	14,000	
	Total				83,000
4.	Highway Relocation				
	14-ft. gravel road	2 mi.	Lump Sum	40,000	
	Contingencies		10%	4,000	
				44,000	
	Engineering and overhead		10%	4,000	
	Total				48,000
5.	Grand Total Capital Cost				$ 429,000
6.	Total Annual Cost				$ 28,100

(18) Birch Hill - No. 65.- (a) General.- The Birch Hill Reservoir, on the Millers River, Massachusetts, about 26.5 miles above the junction with the Connecticut, is outlined on Plate No. 121. The dam site is located about 0.5 mile northeast of South Royalston. The Reservoir is in the Towns of Royalston, Winchendon, and Templeton, in Worcester County, Massachusetts. The 156.3 square miles of net drainage area is mostly brush and second-growth timber. As designed, the capacity is 6.0 inches of run-off from the net drainage area, or 50,000 acre-feet. The flooded area of 3,150 acres at the spillway crest elevation, 847.0 m.s.l., is classified as follows:

(1) Agricultural land 6%

(2) Pastureland 22%

(3) Wooded land 70%

(4) Towns, etc. .... 2% (A small part of the Village of Baldwinsville and several summer cottages near Dennison Lake will be flooded.)

(b) Highways and roads.- Three miles of 18-foot, bituminous macadam, state highway, and 3.2 miles of local, gravel and bituminous macadam roads will have to be relocated.

(c) Railroads.- 3.2 miles of double track main line of the Fitchburg Division of the Boston and Maine Railroad will require relocation along the southern edge of the reservoir and will cross over an arm of the reservoir extending to Baldwinsville.

(d) Other public works.- Three miles of telephone line and 2 miles of steel tower transmission line will have to be relocated. At Waterville dike protection will be provided for a sewage disposal plant owned by the Town of Winchendon.

(e) Dam.- The general design of the dam, the area and capacity curves, and geological features are indicated on Plates Nos. 122 and 123.

(1) Geology.- Rock is buried on the right side to a depth of more than 130 feet below river level. The rock surface rises toward the South beneath semi-pervious sand, gravel, and rock-flour deposits, reaches stream level on the left bank at a depth of about 70 feet, and crops out near the summit of the hill forming the left abutment. Rock crops out again on the south side of this hill, at a height of about 35 feet above stream level. Three rolled-fill embankments are proposed. A spillway and conduit will be excavated in granite, on the north side of the hill, on the left bank of the river.

(2) Available Materials.- Fine sand and rock-flour from the excavation required for the spillway will be suitable for impervious embankment. Other portions of this excavation may be utilized for pervious embankments. Supplementary materials for both pervious and impervious constructions are available within 0.3 mile. Concrete aggregates may be obtained by screening and washing sand and gravel deposits on the right bank within 0.25 mile. Rock from excavation for the spillway and conduit, supplemented by boulders, may be utilized for riprap and toe construction.

(3) Dam and appurtenant works.- Two rolled-fill earth dikes and a rolled-fill earth dam are proposed for this site. The dam will be located across the Millers River, one dike will fill an abandoned railroad cut, and the other will be located in a gap between two hills, now occupied by the Boston & Maine Railroad. The spillway will be excavated in rock on the right side of the hill which rises from the left bank of the river. The spillway weir is a concrete ogee-section, built on rock and is separated from the conduit channel by a concrete retaining wall. The length of the dam across Millers River

is 706 feet, the dike at the abandoned railroad cut is 130 feet, and the dike across the valley occupied by the railroad tracks is 940 feet. The top elevation is 864 feet m.s.l., or about 59 feet above the stream bed. This will allow a freeboard of 5 feet above maximum or spillway-design flood.

(4) Alternate.- No alternate is proposed.

(5) Embankment.- The rolled-fill of the earth sections will be 20 feet wide on top. It will consist of an impervious core from top to bottom with side slopes of about 1 on 1-1/4. This core will be backed by a pervious section on both upstream and downstream faces, the outside slope of which will be a minimum of 1 on 3 up to within 15 feet of the top of the dam. From there to the top the slopes will be 1 on 2-1/2 as a minimum. The upstream slope will be paved with riprap 2-1/2 feet thick. The downstream slopes will be covered with loose rock. A rock-filled trench will be provided at the downstream toe for drainage.

(6) Spillway.- An open ogee section concrete spillway 153 feet long will be constructed on ledge rock. This, with the 22-foot width of Tainter gate, provides a total spillway length of 175 feet. The discharge will be carried in a rock and earth side-hill cut. The right side will be excavated for the conduit channel and lined with concrete for 50 feet above and 200 feet below the gate. The discharge capacity under a 12-foot surcharge is 24,150 second-feet, or the equivalent of 154 second-feet per square mile from the drainage area controlled. The freeboard of 5 feet will be above this 12-foot surcharge. No control will be provided. The spillway weir is so placed that no damage can occur to the toe of the dam from its use. (The 12-foot surcharge was determined upon after studying many possible schemes, which indicated that this surcharge was the most favorable for the design.)

(7) Outlet.- An open intake channel 550 feet long will be provided for the outlet. This will be partly in rock cut. A Tainter gate 27 feet high and 22 feet wide will be provided in the gate section between the spillway and the abutment. The discharge will pass through an outlet channel excavated partly in rock and earth, returning to the river. The discharge capacity at spillway Elevation 847 m.s.l. is 12,000 c.f.s.

(8) Plan of construction.- It is proposed to prepare the foundation of the main dike across the railroad and build it as the excavation for the outlet and spillway progresses. After these are complete, the stream will be diverted and the dam across Millers River and the dike across the old railroad cut will be constructed. The construction period will be about 8 months.

(9) Conservation storage.- Not feasible. Property damage resulting from an increase of flow line elevation will prevent economical development of additional storage.

(Table on following page)

BIRCH HILL - NO. 65

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	220 ac.	Lump Sum	$ 18,000	
	Stream control		" "	2,000	
	Excavation, earth	447,000 cy	$0.40	178,800	
	Excavation, rock	61,400 cy	2.30	141,220	
	Embankment, rolled fill	388,000 cy	0.30	116,400	
	Riprap	14,700 cy	1.50	22,050	
	Concrete, plain	11,200 cy	10.00	112,000	
	Concrete, reinforced	400 cy	12.00	4,800	
	Reinforcing steel	40,000 lbs.	0.06	2,400	
	Gates and machinery		Lump Sum	12,000	
	Miscellaneous		" "	2,500	
				612,170	
	Contingencies		20%	112,830	
				735,000	
	Engineering and overhead		15%	110,000	
	Total				$ 845,000
2.	Relocation of Railroads and Utilities				
	Double-track main line railroad	3.2 mi.	Lump Sum	741,000	
	Telephone lines	3 mi.	" "	2,000	
	Steel tower transmission line	2 mi.	" "	20,000	
	Dike protection for sewage disposal plant		" "	10,000	
				773,000	
	Contingencies		10%	77,000	
				850,000	
	Engineering and overhead		10%	85,000	
	Total				935,000
3.	Rights of Way and Land				
	Land	3,000 ac.	Lump Sum	30,000	
	Buildings purchased	55 sets	" "	200,000	
	Water rights		" "	25,000	
				255,000	
	Legal, overhead, and general expense		20%	51,000	
	Total				306,000
4.	Highway Relocation				
	18-ft. Bit. Mac. state highway	3 mi.	Lump Sum	184,000	
	Local roads, gravel and Bit. Mac.	3.2 mi.	" "	180,000	
				364,000	
	Contingencies		10%	36,000	
				400,000	
	Engineering and overhead		10%	40,000	
	Total				440,000
5.	Grand Total Capital Cost				$2,526,000
6.	Total Annual Cost				$ 138,700

(19) Tully No. 62A.- (a) General.- Tully Reservoir is outlined on Plate No. 124. The dam site is located on the Tully River, about 3.8 miles above the junction with the Millers River, about one mile above Fryeville and 0.1 mile below a highway bridge. The reservoir extends upstream about 2.5 miles, lying in the Town of Royalston, Worcester County, Massachusetts. The drainage area of 50 square miles is hilly, partly wooded and covered with brush. As proposed, the storage capacity will provide for about eight inches of run-off from this watershed, or about 21,300 acre-feet. The flooded area at the spillway crest will be about 1,125 acres, classified as follows:

(1) Agricultural land ..... About 90 acres, of little value, including 2 sets of buildings.

(2) Pastureland .... Included in (1) above.

(3) Wooded land .... About 1,035 acres.

(4) Towns, etc. .... No community center is within the area.

(b) Highways and roads.- A local road to Athol will be relocated around the dam for a distance of 0.8 mile. The construction will be bituminous surface-treated gravel 20 feet wide. A bridge over Tully River will be provided. East and west traffic over a local road will be taken care of by improvement. The road will be raised above the reservoir level. The extent of the improvement will be 0.6 mile and will be constructed of gravel 14 feet wide. Two small structures in this road will be built.

(c) Railroads.- No railroads are located within the area.

(d) Other public works.- About 1.5 miles of telephone and 2.0 miles of steel tower transmission line will be relocated.

(e) Dam.- A general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 125 and 126.

(1) Geology.- On the left side, granite outcrops at the river and rises toward the left abutment under an overburden of sand, rock flour, gravel, and boulders from 5 to 10 feet thick. The rock surface on the right side dips steeply toward the north, reaching a maximum depth of 40 feet below river level. The overburden is essentially the same on both sides.

(2) Available materials.- Deposits of sand and rock flour, suitable for the impervious section, are available on the right bank upstream within 0.5 mile. Sand and gravel for pervious-embankment construction, and for concrete aggregate may be obtained upstream on the right bank within 0.5 mile. Rock from rock excavations, supplemented by boulders, will be available for rock-fill embankment.

(3) Dam and appurtenant works.- A rolled-fill earth dam is proposed, with a tunnel conduit in rock on the left bank. A spillway will be constructed on rock in a saddle located southeast of the left abutment. The dam will be 1,050 feet long. The top elevation is 683 m.s.l., or about 65 feet above the stream bed, and will allow a freeboard of five feet above maximum flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-fill earth embankment will be 25 feet wide on top. It will consist of an impervious core from top to bottom, with sides sloping 1 on 1-1/4, keyed into the ground with a cut-off section along the axis of the dam. The impervious core will be backed with a pervious section on both faces with an outside slope of 1 on 3 from the bottom to within 15 feet of the top, and 1 on 2-1/2 for the remaining 15 feet. A heavy rock fill will be used on the downstream slope, with a rock-filled trench at the bottom of the slope for drainage. The upstream slope will be riprapped. The material for the embankment will be obtained from borrow, utilizing as much of the spoil from the outlet and spillway channel excavations as is suitable.

(6) Spillway.- A saddle spillway weir 180 feet long will be constructed across a gully on the left bank. With the crest at 668 m.s.l., and a 10-foot surcharge, the discharge capacity will be 20,500 c.f.s., or 410 second-feet per square mile from the watershed controlled. A 180-foot wide channel excavated to the rock surface carries the water to the river below.

(7) Outlet.- A conduit, constructed in the left bank, 320 feet long, of which 210 feet is tunnel, lined with concrete, will provide stream-control during construction of the embankment, and reservoir-control later. The cross section will be of a spread horseshoe shape and have an area of 50 square feet. The discharge capacity under the maximum operating head (spillway crest) will be 1,890 second-feet. At the entrance, a gate section will be provided; it will include two 4 by 7.5-foot cast-steel sluice gates, mechanically controlled from a gate house directly above. Trash racks will be provided for the gate openings. The gate house will be accessible by way of a concrete service bridge connecting with the top of the dam. A reinforced concrete stilling basin will be constructed at the discharge end, returning the water to the river with less than scouring velocity.

(8) Plan of construction.- It is proposed first to construct the outlet and gate house, and prepare the ground for the embankment. The stream will then be diverted through the outlet, and the embankment will be constructed simultaneously with the spillway channel excavation. Finally, the spillway weir, the service bridge, and control tower will be constructed. It is estimated that a construction period of about seven months will be required, or one working season.

(9) Conservation storage.- Conservation storage, to the extent of an additional 14.5 inches of run-off, or a net conservation storage of

38,700 acre-feet can be provided with a spillway at elevation 695 m.s.l., at an additional cost of $855,200, or a total cost of $1,429,000 for the development.

(Table on following page)

TULLY - NO. 62A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	300 ac.	Lump sum	$ 25,000	
	Stream control		" "	4,000	
	Excavation, earth	127,000 c.y.	$0.40	50,800	
	Excavation, rock	9,200 c.y.	2.30	21,160	
	Excavation, tunnel	800 c.y.	10.00	8,000	
	Embankment, rolled fill	212,000 c.y.	0.35	74,200	
	Riprap	7,200 c.y.	1.50	10,800	
	Concrete, plain	2,200 c.y.	12.00	26,400	
	Concrete, reinforced	2,300 c.y.	14.00	32,200	
	Reinforcing steel	230,000 lbs.	0.06	13,800	
	Gates and machinery		Lump sum	30,000	
	Gate house and miscellaneous		" "	10,000	
				306,360	
	Contingencies		20%	61,240	
				367,600	
	Engineering and overhead		15%	55,400	
	Total				$423,000
2.	Relocation of Railroads and Utilities				
	Telephone lines	1-1/2 mi.	Lump sum	500	
	Transmission lines	2 mi.	" "	25,000	
				25,500	
	Contingencies		10%	2,500	
				28,000	
	Engineering and overhead		10%	2,800	
	Total				30,800
3.	Rights of Way and Land				
	Land	1,400 ac.	Lump sum	18,500	
	Buildings purchased	2 sets	" "	2,500	
				21,000	
	Legal, overhead and general expense		20%	4,000	
	Total				25,000
4.	Highway Relocation				
	20-ft. Bit. Mac. state highway	0.3 mi.	Lump sum	44,000	
	14-ft. gravel road	0.6 mi.	" "	34,400	
				78,400	
	Contingencies		10%	7,800	
				86,200	
	Engineering and overhead		10%	8,800	
	Total				95,000
5.	Grand Total Capital Cost				$573,800
6.	Total Annual Cost				$ 36,000

(20) Knightville No. 47.- (a) General.- Knightville Reservoir, on the main stream of the Westfield River, about 27.5 miles above its junction with the Connecticut, is outlined on Plate No. 127. The dam site is located just below the highway bridge, in the Village of Knightville, Massachusetts. The reservoir extends up the main stream about six miles, and up the Little River one mile. The reservoir lies in the Towns of Huntington and Worthington, in Hampshire County. The 164 square miles of drainage area is mostly rolling high land, deeply cut by streams, with some cultivation on the plateaus and in the bottomlands. As proposed, the storage capacity will be equivalent to 4.5 inches of run-off from the watershed area above, or 39,300 acre-feet, at the spillway crest elevation, 596.0 m.s.l. At this elevation the reservoir will flood 860 acres of land, of which about half is cleared and partially cultivated. About 22 sets of buildings and a cemetery of 160 graves are in the reservoir area.

(b) Highways and roads.- About 2.5 miles of state highway (No. 112) connecting Huntington and Worthington, and about 3.5 miles of dirt road and one bridge will be inundated. It is estimated that a total of five miles of relocation will be necessary, of which two miles will be new roads and three miles improvements of existing roads. One new bridge will be required. The tentative relocations are indicated on Plate No. 127.

(c) Railroads.- No railroads will be involved.

(d) Other public works.- About three miles of telephone line will require relocation along the highway, the cost of which is included in the estimate for highway relocation.

(e) Dam.- A general design of the dam, the area and capacity curves, and the geologic features are indicated in Plates Nos. 128 and 129.

(1) Geology.- Steeply inclined beds of schist outcrop in the river and throughout the right abutment area. On the left bank the rock surface dips downward and passes under the left end of the dam at a depth of more than 30 feet below river level, or more than 170 feet below the ground surface. The overburden consists of a relatively impervious mixture of sand, rock flour, gravel, and boulders.

(2) Available materials.- Borrow materials are similar to those described above, being essentially mixtures of fine and coarse particles and can be sluiced directly from a borrow area established in the hillside on the left bank. Sand and gravel suitable for concrete aggregate occur in the upper part of a low terrace formation within 0.75 mile upstream. Rock fill for riprap and toe construction may be obtained from the tunnel and spillway excavations, supplemented by boulders from the hydraulic borrow area.

(3) Dam and appurtenant works.- A ground-sluiced hydraulic-fill dam is proposed, with a concrete spillway on the right bank. The length of the earth-fill section is 1,000 feet, top elevation at 611.0 m.s.l. The top will be about 140 feet above the stream bed, allowing a freeboard of five feet above the spillway-design flood. The outlet will consist of a tunnel in the right bank.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The hydraulic-fill dam will be 30 feet wide at the top. It will consist of an impervious core, with shoulders of sand, gravel, and cobbles. The core will be keyed to the impervious foundation except where ledge is close to or at the surface, where a concrete key wall will be used to prevent piping. The slopes in the earth section will be a minimum of 1 on 2-1/2 for the top 15 feet and 1 on 3 for the remainder. The rock used for riprap and rock-filled toe will be obtained from rock excavated from the spillway foundation, spillway channel, and

outlet tunnel.

(6) Spillway.- The spillway, a solid-gravity concrete overflow section 435 feet long, has a crest elevation of 596.0 m.s.l. Under a 10-foot surcharge, the spillway will take care of the design flood of 48,900 c.f.s., or 300 second-feet per square mile of the drainage area. The flood waters passing over the spillway discharge into a rocky draw and return to the river 400 feet below the toe of the dam. The spillway weir is joined to the earth dam by a short section of non-overflow gravity dam.

(7) Outlet.- The reservoir outlet will consist of a tunnel having an area of 216 square feet, excavated through ledge rock on the right bank. The outlet will provide for stream-control during construction of the embankment, and for reservoir-control later. Trash racks are provided at the intake, and a stilling basin at the lower end of the outlet. Control is accomplished by gates operated from a tower located at the upper end of the tunnel. The total capacity of the outlet under maximum operating head (spillway crest elevation) will be 13,600 c.f.s.

(8) Plan of construction.- It is proposed first to construct the tunnel as a means of diverting the river flow. Excavated rock will be used as cofferdams, and will form a part of the permanent structure. Sluicing will commence and continue to spillway elevation. The remainder of the dam will be constructed by rolled-fill method. The spillway and tower will be built simultaneously with the upper portions of the earth dam. The time estimated for construction is 16 months, or two construction seasons.

(9) Conservation storage.- Not feasible. Potential power benefits are low and do not warrant additional construction costs for that purpose.

KNIGHTVILLE - NO. 47

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	300 ac.	Lump Sum	$ 25,000	
	Stream control		" "	15,000	
	Excavation, earth	60,000 c.y.	$0.40	24,000	
	Excavation, rock	14,500 c.y.	2.30	33,350	
	Excavation, tunnel	7,700 c.y.	10.00	77,000	
	Embankment, hydraulic-fill	1,002,000 c.y.	0.40	400,800	
	Riprap (hand-placed)	11,000 c.y.	3.00	33,000	
	Sodding	4 ac.	240.00	960	
	Concrete, plain	12,800 c.y.	10.00	128,000	
	Concrete, reinforced	6,800 c.y.	12.00	81,600	
	Reinforcing steel	680,000 lbs.	0.06	40,800	
	Service bridge		Lump Sum	30,000	
	Gates and machinery		" "	84,000	
	Gate house and miscellaneous		" "	15,000	
				988,510	
	Contingencies		20%	197,490	
				1,186,000	
	Engineering and overhead		15%	178,000	
	Total				$1,364,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	1,800 ac.	Lump Sum	46,000	
	Buildings purchased	22 sets	" "	33,000	
	Cemetery relocation	160 graves	" "	5,000	
				84,000	
	Legal, overhead and general expense		20%	17,000	
	Total				101,000
4.	Highway Relocation				
	20-ft. tarvia state highway 5.0 mi.		Lump Sum	393,000	
	Contingencies		10%	39,000	
				432,000	
	Engineering and overhead		10%	43,000	
	Total				475,000
5.	Grand Total Capital Cost				$1,940,000
6.	Total Annual Cost				$113,300

ALTERNATE RESERVOIRS

(21) Gale River - No. 26.- (a) General.- The Gale River Reservoir, on the Gale River, about 2.8 miles above its confluence with the Ammonoosuc River, is outlined on Plate No. 70. The dam site is located about three miles northwest of Franconia, New Hampshire, and the reservoir extends upstream about three miles, all in the Town of Franconia, in Grafton County. The 86 square miles of drainage area is mostly hilly to mountainous forest lands. As proposed, the storage capacity will provide for 2.9 inches of run-off from the watershed above, or 13,400 acre-feet from empty reservoir to spillway crest. The flooded area at the spillway crest elevation, 912.0 m.s.l., will be 470 acres, classified as follows:

(1) Agricultural land ..... 400 acres, mostly of good quality.

(2) Pastureland .... Included in (1) above.

(3) Wooded land .... 70 acres, partially cut over.

(4) Towns, etc. .... 30 sets of buildings located within the reservoir.

(b) Highways and roads.- About 2-1/4 miles of 14-foot gravel road and 1-1/2 miles of bituminous macadam will be flooded. A tentative relocation is shown on reservoir map, Plate No. 70.

(c) Railroads.- No railroads are involved.

(d) Other public works.- Three miles of telephone and telegraph lines will be relocated.

(e) Dam.- The general design of the dam, the area and capacity curves, and geological features are indicated on Plates Nos. 71 and 72.

(1) Geology.- Granite occurs on the left bank and in the river bed. On the right bank the rock surface dips steeply beneath

relatively impervious glacial deposits composed of sand, rock flour, and gravel. An earth rolled-fill embankment is proposed with the spillway and tunnel conduit located in rock on the left bank.

(2) Available materials.- Materials for the impervious section, consisting chiefly of sand and rock flour, are available upstream within 0.5 mile. Sand and gravel suitable for use as pervious embankment and for concrete aggregate may be obtained upstream on the right bank within 0.5 mile. Rock from spillway and conduit excavations may be utilized for riprap and embankment construction.

(3) Dam and appurtenant works.- A rock-fill dam across the main channel, with a side-channel spillway on the left bank and a low earth-fill dike on the far right bank are proposed. The total length of dam is 630 feet and the dike 960 feet. The top elevation is 927.0 m.s.l., or about 92 feet above the stream bed. This will allow for a freeboard of five feet above the maximum flow line.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rock-fill embankment will be 25 feet wide on top, with side slopes of 1 on 3. The back, or downstream section, will consist of coarse rock. Against the inner face will be a filter section of graded material, varying from coarse gravel to fine sand, and finally an impervious section. The upstream slope will be paved with riprap. Little ground preparation will be needed other than clearing of all vegetable material. Materials will be utilized from the excavation and adjacent borrow pits. The coarse rock fill will provide ample drainage. The earth-fill dike will be 25 feet wide on top. It will consist of an impervious core from top to bottom, with side slopes of 1 on 1-1/2. The core will be backed by a pervious section on both up and downstream faces. The outside slope of each will be 1 on 3, the upstream slope will be paved with riprap, and the outer layer of

the downstream section will be built of heavy stone.

(6) Spillway.- A 290-foot side channel spillway will be constructed in the ledge rock on the left bank. It will discharge flood water into an open concrete-lined channel, which will carry it around the end of the dam and return it to the river below. With the permanent crest at elevation 912.0 m.s.l., the discharge capacity under a 10.0-foot surcharge, the maximum flood, will be 38,000 second-feet, or the equivalent of 440 second-feet per square mile for the watershed above. Five-foot freeboard is provided above the 10.0-foot surcharge. No control will be provided. The quality of rock and the distance downstream from the dam at which the spillway discharge returns to the river are believed adequate to prevent any damage to the dam.

(7) Outlet.- A concrete-lined tunnel 530 feet long, located in the left bank, and having a cross-sectional area of 144 square feet, will provide for stream-control during construction and for reservoir-control later. No gates are provided, the reservoir acting as a retarding basin. Under the operating head, spillway-crest elevation, the outlet capacity will be 6,800 second-feet. A reinforced concrete stilling basin is provided at the discharge end to prevent scour. Trash racks will be provided to prevent clogging of the conduit.

(8) Plan of construction.- It is proposed first to construct the outlet and stilling basin for stream-control, prepare the ground for embankment, and then the spillway will be excavated and lined, using the spoil in the embankment. The upstream side of the embankment will be riprapped as the fill progresses. The time estimated for construction is nine months, or one construction season.

(9) Conservation storage.- Not feasible. Additional storage cannot be provided without flooding the Village of Franconia.

GALE RIVER - NO. 26

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	50 ac.	Lump Sum	$ 4,500	
	Stream control		" "	5,000	
	Excavation, earth	23,400 cy	$0.40	9,360	
	" , rock	142,000 cy	2.00	284,000	
	" , tunnel	2,900 cy	10.00	29,000	
	Backfill at structures	5,300 cy	0.60	3,180	
	Embankment rock-fill	313,000 cy	0.40	125,200	
	Concrete, plain	6,000 cy	10.00	60,000	
	Concrete, reinforced	4,500 cy	12.00	54,000	
	Reinforcing steel	450,000 lbs.	0.06	27,000	
	Miscellaneous		Lump Sum	2,500	
				603,740	
	Contingencies		20%	120,260	
				724,000	
	Engineering and overhead		15%	109,000	
	Total				$ 833,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission lines	3 mi.	Lump Sum	2,000	
	Contingencies		10%	200	
				2,200	
	Engineering and overhead		10%	200	
	Total				$ 2,400
3.	Rights of Way and Land				
	Land	500 ac.	Lump Sum	22,000	
	Buildings purchased	30 sets	" "	90,000	
				112,000	
	Legal, overhead, and general expense		20%	22,000	
	Total				134,000
4.	Highway Relocation				
	18-ft. Bit. Mac. state highway	1.5 mi.	Lump Sum	67,500	
	14-ft. gravel road	2.25 mi.	" "	61,250	
				128,750	
	Contingencies		10%	12,850	
				141,600	
	Engineering and overhead		10%	14,200	
	Total				155,800
5.	Grand Total Capital Cost				$1,125,200
6.	Total Annual Cost				61,000

(22) Bath - No. 69.- (a) General.- The Bath Reservoir is located on the Ammonoosuc River, about 3.1 miles above its confluence with the Connecticut and is outlined on Plate No. 132. The dam site is located about two miles southwest of the Village of Bath, New Hampshire, and the reservoir extends upstream about ten miles in the Towns of Bath, Landaff, and Lisbon, Grafton County, New Hampshire. The 397 square miles of drainage area is hilly to mountainous, mostly forested. As designed, the capacity is 6.0 inches of run-off from the watershed above, or 127,000 acre-feet. The flooded area of 2,500 acres at spillway-crest elevation, 600 m.s.l., is classified as follows:

(1) Agricultural land ..... 2,100 acres of good quality.

(2) Pastureland .... Included in (1) above.

(3) Wooded land .... 400 acres.

(4) Towns, etc. .... The Towns of Lisbon and Bath, which include 270 sets of buildings and two cemeteries of 6,000 graves.

(b) Highways and roads.- About 1.6 miles of 18-foot bituminous-bound macadam state highway, 9.6 miles of 18-foot concrete state highway, and 4.9 miles of 16-foot gravel and bituminous macadam town roads will require relocation.

(c) Railroads.- A single-track branch line of the Boston and Maine Railroad will be relocated.

(d) Other public works.- Twenty-seven miles of telephone and telegraph lines and two miles of transmission line will be relocated.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geological features are indicated on Plate No. 133.

(1) Geology.- Rock occurs throughout the right abutment and in the river bottom. On the left side rock extends to a height of about 60 feet above river level, from which point the rock surface dips

beneath a terrace formation consisting of relatively impervious sand overlaid by pervious sand and gravel. An embankment of earth placed hydraulically is proposed, with a tunnel conduit and spillway constructed on the right side in steeply inclined beds of schist.

(2) Available materials.- Deposits of sand, gravel and rock flour are available on the left bank within 0.5 mile for hydraulic construction. Similar materials, after washing and screening, may be utilized for concrete aggregate. Excavations required for the spillway and conduit will produce rock-fill materials for the outer pervious shell, riprap and toe construction.

(3) Dam and appurtenant works.- A hydraulic-fill dam, with a side-channel spillway on the right bank, is proposed. The total length is 950 feet. The top elevation is 617.0 m.s.l., or about 160 feet above the stream bed. This will allow a freeboard of five feet above maximum flow line.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The earth-fill embankment will be 30 feet wide on top. It will consist of an impervious core from top to bottom, with side slopes of 1 on 1/2, keyed into the ground with a cut-off section along the axis of the embankment. The core will be backed by a pervious section on both up and downstream faces. The upstream slope will be paved with riprap, and the outer layer of the downstream section will be built of heavy stone, with a rock-filled trench along the toe to provide for drainage. The outside slopes will be a minimum of 1 on 3 up to 15 feet from the top of the dam. From there to the top the slopes will be 1 on 2-1/2 as a minimum. Little ground preparation will be needed other than the clearing of all vegetable material. Materials will be utilized from the excavation and ad-

jacent borrow pits.

(6) Spillway.- A 400-foot side-channel spillway will be constructed in the ledge rock on the right bank. It will discharge flood water into an open concrete-lined channel, which will carry it around the end of the dam and return it to the river below the dam. With the permanent crest at elevation 600 m.s.l., the discharge capacity under a 12.0-foot surcharge, the maximum flood, will be 50,300 second-feet, or the equivalent of 127 second-feet per square mile for the watershed above. Five-foot freeboard is provided above the 12.0-foot surcharge. No control will be provided. The quality of the rock and the distance downstream from the dam at which the spillway discharge returns to the river are believed adequate to prevent any damage to the dam.

(7) Outlet.- A concrete-lined tunnel, 870 feet long, located in the right bank, and having a net cross-sectional area of 300 square feet, will provide for stream-control during the construction of the embankment and for reservoir-control later. No gates are provided, the reservoir acting as a retarding basin. Under the operating head, spillway-crest elevation, the outlet capacity will be 9,000 second-feet. A reinforced concrete stilling basin is provided at the discharge end to prevent scour. Trash racks will be provided to prevent clogging of the conduit.

(8) Plan of construction.- It is proposed to construct, first, the outlet and stilling basin for stream-control, prepare the ground for the embankment, and then the spillway will be excavated and lined, using the spoil in the embankment. The upstream side of the embankment will be riprapped as the fill progresses. The time estimated for construction is 16 months, or two construction seasons.

(9) Conservation storage.- Not feasible. Physical limitations of the site and at the Town of Lisbon make additional storage for power uneconomical.

BATH - NO. 69

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	200 ac.	Lump Sum	$ 16,000	
	Stream control		" "	20,000	
	Excavation, earth	34,500 cy	$0.40	13,800	
	Excavation, rock	159,000 cy	2.00	318,000	
	Excavation, tunnel	9,800 cy	10.00	98,000	
	Embankment, hydraulic-fill	1,144,000 cy	0.40	457,600	
	Riprap	20,000 cy	1.50	30,000	
	Concrete, plain	15,800 cy	10.00	158,000	
	Concrete, reinforced	10,800 cy	12.00	129,600	
	Reinforcing steel	1,620,000 lbs.	0.06	97,200	
	Miscellaneous		Lump Sum	20,000	
				1,358,200	
	Contingencies		20%	271,800	
				1,630,000	
	Engineering and overhead		15%	244,000	
	Total				$1,874,000
2.	Relocation of Railroads and Utilities				
	Single-track branch railroad	10.3 mi.	Lump Sum	2,600,000	
	Telephone lines	27 mi.	" "	27,000	
	Transmission lines	2 mi.	" "	4,000	
				2,631,000	
	Contingencies		10%	263,000	
				2,894,000	
	Engineering and overhead		10%	289,000	
	Total				3,183,000
3.	Rights of Way and Land				
	Land	2,900 ac.	Lump Sum	210,000	
	Buildings purchased	270 sets	" "	1,958,000	
	Water rights		" "	60,000	
	Cemetery relocation	6,000 graves	" "	180,000	
				2,408,000	
	Legal, overhead and general expense		20%	482,000	
	Total				2,890,000
4.	Highway Relocation				
	18-foot Bit. Mac. state highway	1.6 mi.	Lump Sum	110,000	
	18-foot concrete state highway	9.6 mi.	" "	706,000	
	Local road, gravel and Bit. Mac.	4.9 mi.	" "	132,500	
				948,500	
	Contingencies		10%	94,800	
				1,043,300	
	Engineering and overhead		10%	104,700	
	Total				1,148,000
5.	Grand Total Capital Cost				$9,095,000
6.	Total Annual Cost				$ 518,500

(23) Centerville - No. 70.- (a) General.- The reservoir is located on the main stream of the White River, Vermont, six miles above its junction with the Connecticut River, as outlined on Plate No. 134. The dam site is located about two miles above the Village of Centerville. The reservoir extends upstream about 17-1/2 miles on the White River, 3-1/4 miles up First Branch, 2-1/4 miles up Second Branch, and lies in the Towns of Hartford, Sharon, and Royalton, all in Windsor County. The 692 square miles of drainage area includes a variety of topographic features, but is mostly wooded mountains. As designed, the storage capacity will be equivalent to 4.2 inches of run-off from the watershed, or 155,000 acre-feet at spillway-crest elevation, 508 m.s.l. At this elevation the flooded area will be 3,300 acres, classified as follows:

(1) Agricultural land ..... 2000 acres of considerable value including 32 sets of buildings.

(2) Pastureland .... 700 acres.

(3) Wooded land .... 600 acres.

(4) Towns, etc. .... Towns of West Hartford and Sharon will be inundated including 138 sets of buildings and a cemetery of 800 graves.

(b) Highways and roads.- The reservoir will inundate 15.4 miles of first-class highway and 8.0 miles of gravel roads. It will be necessary to relocate a new first-class highway on the left bank, 19.6 miles in length, and 5.3 miles of gravel road on the right bank. The tentative relocations are indicated on Plate No. 134.

(c) Railroads.- A considerable portion of the total cost of this project will be railroad relocation. The single-track line of the Central Vermont Railroad, an important link in the system, runs through the valley, and 14.2 miles of line is in the reservoir. In relocating the railroad, the right bank was selected as being the most advantageous.

The new line, located on the right bank, will have a total length of 16 miles.

(d) Other public works.- There are about 40 miles of telephone and power lines in the reservoir area which will require relocation.

(3) Dam.- The general design of the dam, the area and capacity curves, and the geological features are indicated on Plate No. 135.

(1) Geology.- Subsurface investigations have not been made at this site. However, the surface geological features indicate favorable conditions for construction of the proposed structures. Schist occurs on the left bank from river level to heights well above the top of dam. Rock on the right bank lies at an undetermined depth beneath a glacial terrace made up chiefly of sand and gravel.

(2) Available materials.- Sand and gravel, suitable for concrete aggregate, are available on both banks within 0.5 mile. Earth materials, both for pervious and impervious embankment construction, may be obtained on the right bank within 0.25 mile. Rock excavations in the left abutment area will furnish rock fill for riprap and drainage toe construction.

(3) Dam and appurtenant works.- A concrete-and-earth dam is proposed, having a total length of 1,420 feet. The top elevation of the earth section will be at Elevation 529 m.s.l., and the top of the concrete nonoverflow section at Elevation 524. The maximum height of the earth section will be 60 feet, and that of the concrete section 175 feet. The spillway will be a concrete overflow section located over the existing river bed, and the outlets will be a battery of conduits passing through the base of the spillway section.

(4) Alternate.- There is an alternate dam site located 6-1/4 miles downstream, referred to as Hartford, No. 67, having less capacity and more expensive railroad relocation.

(5) Embankment.- On the right bank is a flat terrace where it has been found economical to use an earth section. It will be a rolled-fill structure 20 feet wide at the top. The impervious core will be covered by shoulders of pervious material having outside slopes of 1 on 2-1/2 on the top 15 feet and 1 on 3 for the remainder. The upstream face will be protected by riprap, and the downstream toe provided with a rock toe for drainage purposes.

(6) Spillway.- The spillway, a solid-gravity concrete overflow dam, 310 feet long, has a crest elevation of 508.0 m.s.l. Under a 16-foot surcharge the spillway will take care of the design flood of 75,200 c.f.s., or 109 second-feet per square mile of drainage area. Considering the quantity of water to be discharged over the spillway and the geological features at the site, it was found that the combination of a length of 310 feet with a surcharge of 16 feet was most economical. The length of the spillway is but slightly greater than the width of the river, so that the discharge is returned directly to the river bed below the dam.

(7) Outlets.- The reservoir outlets will consist of eight conduits passing through the spillway section at an elevation which will permit proper functioning of the deflectors, the purpose of which is to dissipate the energy of the water. Two of the eight conduits will be automatic; that is, they will have no gates and will discharge at all times. The remaining six will be provided with 5.67-foot by 10.0-foot gates, hydraulically operated. The total capacity of the outlets under maximum operating head (spillway-crest elevation) will be 35,100 c.f.s.

(8) Dikes.- To prevent inundation of the Villages of Royalton and South Royalton, about 13 miles upstream from the dam, low dikes will be constructed, having lengths of 3/4 mile and one mile,

respectively. The top elevation 513 m.s.l. will have a width of ten feet, and the slopes 1 on 2-1/2 on the reservoir side and 1 on 2 on the land side. A small brook will be diverted through a ditch 500 feet long at South Royalton, and provision will be made at both villages for drainage and sewage disposal at all times.

(9) Plan of construction.- It is proposed to construct the dam in two construction seasons. To close the river, a section of the dam is constructed within crib cofferdams to an elevation above minor floods, extending about two-thirds across the river; then the remainder of the river is cofferdammed off, diverting the flow through the constructed conduits. About half of the earth section will be built from earth excavated from the right bank where the concrete nonoverflow section is to be built. As this concrete section goes up the backfill will be placed. The dikes at Royalton and South Royalton may be built when the main dam is complete. A portion of the earth excavation at the dam site may be used to advantage in the railroad relocation.

(10) Conservation storage.- Not justified. The additional cost of rights-of-way and relocation involved makes further extension prohibitive.

(Table on following page)

CENTERVILLE - NO. 70

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	500 ac.	Lump Sum	$ 40,000	
	Stream control		" "	25,000	
	Excavation, earth	260,000 cy	$0.40	104,000	
	Excavation, rock	15,000 cy	2.30	34,500	
	Embankment, rolled earth	826,000 cy	0.45	371,700	
	Riprap	16,700 cy	1.50	25,050	
	Sodding	20 ac.	240.00	4,800	
	Concrete, plain	228,000 cy	9.00	2,052,000	
	Concrete, reinforced	1,800 cy	12.00	21,600	
	Reinforcing steel	220,000 lbs.	0.06	13,200	
	Gates and machinery		Lump Sum	201,000	
	Gate house and miscellaneous		" "	25,000	
				2,917,850	
	Contingencies		20%	583,150	
				3,501,000	
	Engineering and overhead		15%	525,000	
	Total				$4,026,000
2.	Relocation of Railroads and Utilities				
	Single-track main line railroad	16 mi.	Lump Sum	2,460,000	
	Telephone and transmission lines		" "	20,000	
				2,480,000	
	Contingencies		10%	248,000	
				2,728,000	
	Engineering and overhead		10%	273,000	
	Total				3,001,000
3.	Rights of Way and Land				
	Land	3,850 ac.	Lump Sum	200,000	
	Buildings purchased	170 sets	" "	480,000	
	Cemetery relocation	800 graves	" "	25,000	
	Water rights		" "	20,000	
				725,000	
	Legal overhead and general expense		20%	145,000	
	Total				870,000
4.	Highway Relocation				
	18-foot Bit. Mac. state highway	19.6 mi.	Lump Sum	1,321,000	
	14-foot gravel town roads	5.3 mi.	" "	185,500	
				1,506,500	
	Contingencies		10%	150,500	
				1,657,000	
	Engineering and overhead		10%	166,000	
	Total				1,823,000
5.	Grand Total Capital Cost				$9,720,000
6.	Total Annual Cost				$ 540,300

(24) West Canaan - No. 66.- (a) General.- West Canaan Reservoir, on the Mascoma River, New Hampshire, about 19.5 miles above its junction with the Connecticut River, is outlined on Plate No. 130. The dam site is about 1-1/2 miles east of West Canaan, New Hampshire, and the reservoir extends upstream on the Mascoma River, about 4 miles, to the low tailwater of the existing dam (R. S. Roby) just below Canaan Center, and up the Indian River about 2-1/2 miles to the lower limits of the Village of Canaan, all in the Town of Canaan, in the County of Grafton. The drainage area of 80 square miles is hilly to mountainous farm land and woods. The flood-storage capacity, as proposed, will provide for about 6 inches of run-off from the drainage area above, or about 25,700 acre-feet from empty reservoir to spillway-crest. The flooded area at spillway-crest, 893.0 m.s.l., will be about 1,370 acres; about 550 acres is thickly wooded; about 370 acres is swamp land covered with low brush, and about 450 acres is low hay land.

(b) Highways and roads.- State Highway No. 4 will need relocation. It is proposed to locate it to the south of the reservoir, the new location being about 4.6 miles. The construction will involve a great deal of side-hill grading in heavy boulders; the pavement will be bituminous macadam.

(c) Railroads.- About 4.7 miles of single-track main line of the Boston and Maine Railroad will need relocation. It is proposed to locate the railroad along the south rim of the reservoir. In order to keep the grade within a maximum compensated grade of 0.7 per cent, it will be necessary to start the relocation back at the Enfield-Canaan Town Line, thence bearing off to the southeast, and thence back along the reservoir. The line will be about 1,000 feet longer, but the final grade as a whole will be better than the existing grade between Enfield and Canaan.

(d) Other public works.- About 4.6 miles of telephone line and a like distance of electric power distribution pole line will require relocation. It is proposed to locate them along the new highway.

(e) Dam.- A general design of the dam and the area and capacity curves are indicated on Plate No. 131.

(1) Geology.- Little is definitely known of the subsurface conditions. The river has cut deeply into glacial deposits, and the location of the rock floor is uncertain. The overburden is composed essentially of a mixture of sand, gravel, and rock flour. Numerous large boulders are accumulated in the stream bed, on the valley slopes and in the higher ground on either side.

(2) Available materials.- Concrete aggregates may be obtained upstream within 0.5 mile. Screening and washing of the sand and gravel deposits is desirable. Crushed cobbles and boulders will furnish a supplementary supply of coarse aggregate.

(3) Dam and appurtenant works.- A concrete, gravity-type dam, is proposed, 610 feet long, extending across the entire valley. It will consist of an overflow section 270 feet long on the left, with a gate section 24 feet long to the right of the spillway, and the remainder non-overflow section. The top of the non-overflow section will be at elevation 901.0 m.s.l., or 53 feet above the stream bed.

(4) Alternate.- No alternate is proposed.

(5) Embankment.- No embankment is proposed in connection with the dam.

(6) Spillway.- An open concrete overflow section, 270 feet long, with a crest at 893.0 m.s.l., will be provided across the present channel and extended on to the left bank. The left end will be keyed into the rock with a short non-overflow section about 55 feet long.

With a surcharge of 8 feet to the top of the non-overflow dam, the discharge capacity of the spillway will be about 22,000 c.f.s., or the equivalent of about 275 second-feet per square mile of drainage area controlled. The stilling effect resulting from a well-filled channel below, and the stability offered to the natural stream bed by the mat of heavy boulders, will prevent any damage from the use of the spillway.

(7) Outlet.- A mass-concrete gate section 24 feet long will be provided at the right end of the overflow section; the gate house to be located below the axis of the dam, with operating floor at Elevation 870 m.s.l. An approach-and-exit channel 30 feet wide will be excavated, the sides and the bottom to be lined with concrete. The gates, two 6 x 8-foot gates, with reservoir level at spillway-crest, will discharge about 3,600 second-feet.

(8) Plan of construction.- Before construction can proceed at the dam site, it will be necessary to relocate the railroad and highway, which will require about one working season. To start the dam construction, the gate section will be built, the new channel made, and gates installed. The stream will then be diverted through the gate section and the spillway built; and, finally, the non-overflow section will be completed. The whole job of railroad and highway relocation, together with the dam construction, is estimated to require about 20 months, or two construction seasons.

(9) Conservation storage.- Conservation storage for power to the extent of about five inches of run-off or 21,300 acre-feet, in addition to the storage for flood control is justified, and can be obtained at an additional cost of $244,000 or a total cost for the development of $2,020,000.

WEST CANAAN - NO. 66

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing		Lump Sum	$ 1,900	
	Stream control		" "	6,000	
	Excavation, earth	13,400 cy	$0.40	5,360	
	Excavation, rock	9,500 cy	3.00	28,500	
	Concrete, plain	13,000 cy	10.00	130,000	
	Concrete, reinforced	3,900 cy	12.00	46,800	
	Reinforcing steel	600,000 lbs.	0.06	36,000	
	Gates and machinery		Lump Sum	30,000	
	Gate house and miscellaneous		" "	13,000	
				297,560	
	Contingencies		20%	59,440	
				357,000	
	Engineering and overhead		15%	54,000	
	Total				$ 411,000
2.	Relocation of Railroads and Utilities				
	Single-track branch railroad	4.7 mi.	Lump Sum	820,000	
	Telephone and transmission lines	9.2 mi.	" "	5,000	
				825,000	
	Contingencies		10%	83,000	
				908,000	
	Engineering and overhead		10%	91,000	
	Total				$ 999,000
3.	Rights of Way and Land				
	Land	1,400 ac.	Lump Sum	35,000	
	Buildings purchased	16 sets	" "	45,000	
	Water rights		" "	5,000	
				85,000	
	Legal, overhead, and general expense		20%	17,000	
	Total				102,000
4.	Highway relocation				
	20-ft. Bit. gravel state highway	4.6 mi.	Lump Sum	218,500	
	Contingencies		10%	21,500	
				240,000	
	Engineering and overhead		10%	24,000	
	Total				264,000
5.	Grand Total Capital Cost				$1,776,000
6.	Total Annual Cost				$ 104,800

(25) Mascoma Lake - No. 72.- (a) General.- Mascoma Lake Reservoir on the Mascoma River, New Hampshire, about 10.2 miles above its junction with the Connecticut River, is outlined on Plate No. 136. The dam site is located about 2 miles west of Enfield, New Hampshire, and the reservoir includes Mascoma Lake extending up the Mascoma River 2-1/2 miles and up the Knox River a like distance. The dam site and the lower 3/4 mile of the reservoir lies in the Town of Lebanon, the remainder of the reservoir in the Town of Enfield, all in the County of Grafton. The drainage area of 153 square miles is hilly farmland for the most part, embracing several villages. As proposed, the flood storage capacity will provide for about 2.1 inches of run-off from the gross drainage area above, or about 17,000 acre-feet as a surcharge upon 11,400 acre-feet of power storage. The flooded area to the spillway crest, 759.0 m.s.l., will be about 1,620 acres, about 1,400 of which represents the existing Mascoma Lake surface. The 220 acres beyond the existing lake outline consists mostly of beaches for a part of which only flowage rights will be procured; about 30 acres will require purchase, including 15 sets of buildings. About 60 summer cottages and 10 boat houses will need raising on their foundation, by various amounts ranging from 2 to 8 feet.

(b) Highways and roads.- No highways will need relocation, but several small culverts at the upper end of the lake will need to be raised. A new bridge across the Mascoma River, on the Shaker highway out of Enfield will be required, also a new bridge across the lake. This Shaker highway will need to be detoured during extreme flood stages owing to the flooding of the railroad underpass.

(c) Railroads.- About 1.3 miles of main line track and one mile of siding of the Boston and Maine railroad will be raised about

5 feet.

(d) Other public works.- None other involved.

(e) Dam.- A general design of the dam and the area capacity curves are indicated on Plate No. 137.

(1) Geology.- Detailed information as to subsurface conditions is lacking. The rock surface underlies a glacial overburden of uncertain thickness. An estimate has been prepared based largely upon explorations by means of soundings and auger borings, which indicated evidence of rock on the left bank near the stream. The right bank is composed of a mixture of sand, gravel and rock flour, together with boulders.

(2) Available materials.- Sand and gravel deposits are available within 0.5 miles, for use as concrete aggregate. Screening and washing are desirable. Embankment materials consisting of sand, gravel and rock flour may be obtained on the right bank within 0.5 mile.

(3) Dam and appurtenant works.- A concrete gravity-type non-overflow section is proposed for the left abutment, a concrete overflow and gate section across the main channel, and a rolled-earth fill on the right bank. The total length of dam is 920 feet, 540 feet being earth fill with a top elevation of 776.0 m.s.l., 40 feet above the stream bed. The earth fill will be open at the railroad. The opening is supported by retaining walls provided with grooves to receive stop logs in case of extreme flood. Considering a surcharge of 12 feet on the spillway crest, the non-overflow concrete section will provide for no freeboard, the earth fill will provide for a 5-foot freeboard above the surcharge.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-earth fill will be made 20 feet wide on top. It will consist of an impervious core from top to

bottom, keyed into the ground with a cut-off section about 5 feet deep along the axis of fill; side slopes of the core will be 1 on 1-1/2. The core will be backed by a section of pervious material on both the upstream and downstream faces, the outside slopes to be 1 on 2-1/2; the upstream slope will be paved with riprap. The left end of the earth fill will abut concrete retaining walls at the gate house section. Materials for the earth fill will be obtained from borrow near the site, the spoil from the spillway and channel excavation to be utilized as adaptable.

(6) Spillway.- An open gravity-type concrete overflow spillway section, 170 feet long, will be built on the rock ledge in the main channel and extending into the left bank. The left end will be keyed into the slope with a short non-overflow section of concrete. With a permanent crest at Elevation 759.0 m.s.l., the discharge capacity under a 12-foot surcharge will be about 28,000 c.f.s., or the equivalent of 184 second-feet per square mile from the drainage area above.

(7) Outlet.- A mass-concrete gate section 50 feet long will be provided at the right end of the spillway. The existing stream bed will be excavated to allow an ultimate draw down of the Mascoma Lake to Elevation 737.0 m.s.l. The gate sill will be made Elevation 737.0 and a 50-foot wide free inlet channel to the gate section will be dredged back to the 735.0 contour of the lake. On the downstream side of the gate section, the low water channel will be dredged for a distance of several hundred feet to provide free discharge at low stages. The capacity of the 4 - 6 x 8-foot gates is about 4 times as much as would be needed for flood control purposes. This is because the outlet capacity must be adaptable to the needs of the power interests who will take the water under low heads. Were all gates opened under a maximum head, at

a flood time with reservoir level at spillway crest, the outlet discharge capacity would be about 5,000 c.f.s.

(8) Plan of construction.- It is proposed to use the existing dam and outlet for stream control during construction. The proposed gate section and walls on the downstream side will first be constructed, the earth-fill started, and the dredging of the outlet below the dam completed. Then for a short period the old dam will be opened, the lake drawn down and the new inlet channel excavated; completing the upstream retaining wall and earth-fill at the same time. The flow will then be diverted through the new gate section and the spillway section built, finally, the non-overflow section in the left bank will be completed and the upstream toe of the earthfill riprapped. The time estimated for construction is about 10 months, or one long working season.

(9) Conservation storage.- The proposal for flood constrol conserves about 11,400 acre-feet of existing power storage. To provide additional power storage is not economically justified owing to expensive relocations and rights of way required.

(Table on following page)

MASCOMA LAKE - NO. 72

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing		Lump Sum $	2,300	
	Stream control		" "	6,500	
	Excavation, earth	22,000 c.y.	$0.40	8,800	
	Excavation, rock	6,500 c.y.	3.00	19,500	
	Embankment, rolled-fill	42,000 c.y.	0.80	33,600	
	Concrete, plain	9,500 c.y.	10.00	95,000	
	Concrete, reinforced	2,300 c.y.	12.00	27,600	
	Reinforcing steel	350,000 lbs.	0.06	21,000	
	Gates and machinery		Lump Sum	35,000	
	Gate house and miscellaneous		" "	12,000	
				261,300	
	Contingencies		20%	52,700	
				314,000	
	Engineering and overhead		15%	47,000	
	Total				$361,000
2.	Relocation of Railroads and Utilities				
	Single-track branch railroad	1.3 mi.	Lump Sum	161,000	
	Contingencies		10%	16,000	
				177,000	
	Engineering and overhead		10%	18,000	
	Total				195,000
3.	Rights of Way and Land				
	Land	200 ac.	Lump Sum	15,000	
	Buildings purchased		" "	115,000	
	Water rights		" "	10,000	
				140,000	
	Legal, overhead, and general expense		20%	28,000	
	Total				168,000
4.	Highway Relocation				
	Bridges and culverts		Lump Sum	180,000	
	Contingencies		10%	18,000	
				198,000	
	Engineering and overhead		10%	20,000	
	Total				218,000
5.	Grand Capital Cost				$942,000
6.	Total Annual Cost				$ 57,400

(26) Stocker Pond No. 53A.- (a) General.- This reservoir, on Stocker Brook, which is tributary to Croydon Branch of the Sugar River, New Hampshire, is outlined on Plate No. 94. The dam site is located about 3/4 mile east from Grantham, New Hampshire, and the reservoir extends upstream about 3-3/4 miles along the town line of, and into the Towns of Grantham and Springfield, of Sullivan County. The drainage area of 35.4 square miles is hilly farm land for the most part, embracing a number of village community centers. As designed, the storage capacity would provide for about 6.0 inches of run-off from the watershed above, or about 11,300 acre-feet. The flooded area at the spillway-crest (1,032.0 m.s.l.) would be 1,060 acres, classified as follows:

(1) Agricultural land.....	600 acres, of low quality, including 10 sets of buildings.
(2) Pastureland	Included in (1) above.
(3) Wooded land	460 acres.
(4) Towns, etc.	One cemetery consisting of 450 graves will need to be relocated.

(b) Highway and roads.- Proposed relocation of highways are indicated on reservoir map, Plate No. 94. Highway relocation will replace the Grantham-Springfield state aid road and will be bituminous macadam construction four and four-tenths (4.4) miles long, eighteen (18) feet wide. The proposed relocation will begin below the dam site near the Village of Grantham, running in a southerly direction towards Cranberry Pond, around the reservoir toward Sanborn Pond. A local dirt road will be improved for 1.6 miles of this relocation, while 2.8 miles will be new road.

(c) Railroads.- No railroads will be involved.

(d) Other public works.- One mile of country telephone line will require relocation.

(c) Dam.- The general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 95 and 96.

(1) Geology.- Granite gneiss occurs at spillway elevation in the right abutment beneath 20 feet of very compact sand, rock fragments, and rock flour (glacial till). The rock surface is exposed in the stream, but dips southerly beneath the left abutment. This abutment is composed essentially of the same glacial till as that in the right abutment.

(2) Available materials.- Suitable impervious material for the relatively small embankment volume is available near the site. Excavation of overburden for the spillway in the right abutment will furnish a portion of the embankment material. Similar material is also available in deposits within 0.5 mile upstream. Gravel and sand deposits for pervious embankment construction, and for concrete aggregate, are located about 1.0 mile upstream. Elimination of rock flour in the fine aggregate is desirable.

(3) Dam and appurtenant works.- A rolled-fill earth and rock dam across the main channel, with a concrete abutment and side-hill type concrete spillway on the right bank, is proposed. The total length of the embankment is 360 feet. The top elevation is 1,047 m.s.l., or about 48 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum flood-line.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled earth-fill and rock embankment will be 20 feet wide on top. It is to consist of an impervious core from top to bottom, keyed into the ground with a cut-off section along the axis of the dam, side slopes of impervious core to be 1 on 1-1/2. The core is to be backed by a pervious section on both up and downstream

faces, the outside slope of each to be 1 on 3 from bottom up to within 15 feet of the top, the top 15 feet to be 1 on 2-1/2. The upstream slope will be paved with a 2-1/2-foot layer of riprap; the outer layer of the downstream section will be built of heavy cobbles or field stone, with a rock-filled trench about 5 feet deep along the toe to provide for subsurface drainage. For the most part, materials from the excavation will be utilized, borrow being resorted to as needed.

(6) Spillway.- An open concrete-weir type spillway 55 feet long is to be provided on the right bank. The discharge will be carried around the end of the dam, in a concrete-lined channel excavated in rock, and returned to the river well below the toe of the dam. With the permanent crest at Elevation 1032.0 m.s.l., the discharge capacity under a 10-foot head (the maximum flow-line) will be about 5,400 second feet, or the equivalent of about 154 second-feet per square mile from the drainage area controlled. The freeboard of 5 feet will be above this 10-foot surcharge. No control will be provided. The discharge end of the spillway channel will be located far enough downstream from the toe of the dam, and the discharge so guided that any resulting scour will not reach the dam.

(7) Outlet.- A reinforced concrete conduit, located on the right bank, and having a cross-sectional area of 42 square feet, will provide for stream-control during construction of the embankment and for reservoir-control later. No gates are to be provided, the reservoir acting as a retarding basin. Under the operating head (spillway-crest) the outlet capacity will be about 1,400 second-feet. A reinforced concrete stilling basin is to be provided at the discharge end to prevent scour; the water will be carried about 60 feet below the downstream toe of the embankment.

(8) Plan of construction.- It is proposed to construct

first the outlet and stilling basin for stream-control and prepare the ground for the embankment; then, the spillway is to be excavated, using the spoil in the embankment. Finally, the embankment will be completed and the spillway channel lined. The upstream side of the embankment is to be riprapped as the fill progresses. The time estimated for construction is about seven months, or one construction season.

(9) Conservation storage.- Conservation storage at this site is economically justified to the extent of 8,770 acre-feet or 4.7 inches of run-off, which will raise the spillway to Elevation 1039. The additional cost of providing this storage is $82,400, making a total cost of $592,000 for the development.

(Table on following page)

STOCKER POND - NO. 53A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	300 ac.	Lump Sum	$ 23,500	
	Stream control		" "	5,000	
	Excavation, earth	50,000 c.y.	$0.40	20,000	
	Excavation, rock	12,000 c.y.	2.30	27,600	
	Embankment, earth	67,000 c.y.	0.30	20,100	
	Concrete, plain	2,500 c.y.	12.00	30,000	
	Concrete, reinforced	900 c.y.	14.00	12,600	
	Reinforcing steel	90,000 lbs.	0.06	5,400	
	Miscellaneous		Lump Sum	2,000	
				146,200	
	Contingencies		20%	29,800	
				176,000	
	Engineering and overhead		15%	26,000	
	Total				$202,000
2.	Relocation of Railroads and Utilities				
	Telephone lines	1 mi.	Lump Sum	500	
	Contingencies		10%	50	
				550	
	Engineering and overhead		10%	50	
	Total				600
3.	Rights of Way and Land				
	Land	1,500 ac.	Lump Sum	22,000	
	Buildings purchased	10 sets	" "	25,000	
	Cemetery relocation	450 graves	" "	14,000	
				61,000	
	Legal, overhead and general expense		20%	12,000	
	Total				73,000
4.	Highway Relocation				
	20-ft. tarvia state highway, bridge	4.4 mi.	Lump Sum	193,500	
	Contingencies		10%	19,300	
				212,800	
	Engineering and overhead		10%	21,200	
	Total				234,000
5.	Grand Total Capital Cost				$509,600
6.	Total Annual Cost				$ 30,500

(27) Ludlow No. 36.- (a) General.- The Ludlow Reservoir, located on the upper reach of the Black River, Vermont, is about 28 miles above the junction of the Black and Connecticut Rivers. The dam is located about three-quarters of a mile northwest from Ludlow, Vermont, and the reservoir extends upstream about 4-3/4 miles to the Village of Tyson, at the head of Rescue Lake, lying almost wholly in the Town of Ludlow, except where it touches the lower limits of Tyson in the Town of Plymouth, all in Windsor County. The 56 square miles of drainage area is hilly to mountainous; the hilltops are wooded and some of the hillsides are farmed. As designed, the storage capacity would provide for about 4.5 inches of run-off from the watershed above, or about 13,400 acre-feet from empty reservoir to spillway crest. The flooded area at the spillway crest (1,057.0 m.s.l.) will be about 640 acres, about 320 acres of which is Rescue Lake; the remainder is classified as follows:

(1) Agricultural land ..... 240 acres of considerable value, including about 20 sets of buildings.

(2) Pastureland .... Included in (1) above.

(3) Wooded land .... 80 acres.

(4) Towns, etc. .... About 50 summer cottages located around the lake will require removal to higher ground.

(b) Highways and roads.- 2.1 miles of 20-foot-wide, concrete state highway and 2.7 miles of 18-foot-wide, bituminous macadam will require relocation. About a half-mile of connecting road across the reservoir must be raised and will require construction of a bridge. The tentative plan of relocation is sketched on reservoir map, Plate No. 100.

(c) Railroads.- About a mile of railroad skirts the lower right end of the reservoir, but it is located well above the reservoir level.

(d) Other public works.- About 10 miles of telephone and transmission pole-line will need to be relocated.

(e) Dam.- The general design of the dam, the area and capacity curves, and the geologic features are indicated on Plates Nos. 101 and 102.

(1) Geology.- The right abutment rises steeply from river level and is formed entirely in schist. The rock surface dips eastward to undetermined depths beneath the river and the left abutment. Interstratified sand, gravel, rock flour and cobbles are deposited under the flood plain and the left abutment.

(2) Available materials.- As the spillway and outlet conduit will be constructed in rock in the right abutment, and since impervious rolled-fill material of fine sand and silt is available in the valley bottom within one-half mile upstream, ample suitable materials are available for a rolled-fill dam with heavy rock shoulders. Large quantities of sand and gravel suitable for pervious embankment as well as for concrete aggregate are available upstream along the lower left or east side of the valley. An alternative borrow area, containing material suitable for all purposes of construction, is located within 1/2 mile east of the left abutment.

(3) Dam and appurtenant works.- A rolled earth-fill across the main river channel is proposed, with a spillway, apart from the embankment, cut through the rock fill in the right bank. The length of the earth-fill will be about 570 feet; the top elevation at 1,072 m.s.l. rises about 83 feet above the stream bed; it will allow a freeboard of 5 feet above the spillway-design flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled earth-fill will be 20 feet

wide on top. It will consist of an impervious core from top to bottom. A concrete key wall will be provided at the rock surface on the right bank to the edge of the river, on the left bank a trench filled with impervious material will be provided. The impervious core will be backed on both the upstream and downstream faces with a pervious section, with outside slopes of 1 on 3 from bottom to within 15 feet of the top, the top 15 feet to be 1 on 2-1/2. To prevent seepage through the left abutment an impervious blanket will be provided under the upstream pervious section and above the upstream toe. At the downstream slope a rock-filled trench will provide drainage. The fill materials will be obtained mostly from borrow pits; spoil from the spillway excavation will be utilized where adaptable.

(6) Spillway.- A 172-foot side-channel spillway constructed in the ledge on the right hillside, will discharge flood water into an open rock cut lined with concrete, which will carry the discharge through the hillside, returning it to the river about 500 feet below the toe of the dam. With a permanent crest at 1057.0 m.s.l., the capacity under a surcharge of 10 feet (maximum flood level) will be about 17,400 c.f.s., or the equivalent of 310 second-feet per square mile from the drainage area above. The spillway will be open and without control. The quality of the rock and the distance downstream from the dam at which the spillway discharge returns to the river are believed adequate to prevent any damage to the dam.

(7) Outlet.- A semicircular reinforced-concrete conduit, constructed in a rock cut along the right bank, will provide for stream-control during the construction of the earth fill, and for reservoir-control later. It will have a cross-sectional area of 98 square feet, and with pond at elevation of spillway crest, the discharge capacity will be 4,500 c.f.s. At the entrance, three cast-steel sluice gates

together with one emergency gate will be provided. The gates will be mechanically operated from a gate house immediately above; the house will be accessible by way of a service bridge connecting with the top of the embankment. At the discharge end, a reinforced-concrete stilling basin will return the water to the river well below the toe of the dam.

(8) Plan of construction.- It is proposed first to construct the outlet and gate house, including service bridge piers. The stream will then be diverted through the outlet and the rolled-fill embankment constructed simultaneously with the spillway excavation. The impervious blanket and riprap will be placed as the fill progresses. Finally, the spillway weir will be constructed, the spillway channel lined, and the service bridge constructed. It is estimated that the time of construction will be about eight months, or a full working season.

(9) Conservation storage.- Not feasible. A higher spillway level will cause excessive property damage at the Village of Tyson in the upper end of the reservoir area.

(Table on following page)

LUDLOW - NO. 36

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	250 ac.	Lump Sum	$ 20,000	
	Stream control		" "	4,000	
	Excavation, earth	28,200 cy	$0.40	11,280	
	Excavation, rock	124,000 cy	2.00	248,000	
	Backfill at structures	15,300 cy	0.60	9,180	
	Embankment, rolled fill	315,000 cy	0.35	110,250	
	Concrete, plain	4,600 cy	10.00	46,000	
	Concrete, reinforced	5,300 cy	12.00	63,600	
	Reinforcing steel	620,000 lbs.	0.06	37,200	
	Gates and machinery		Lump Sum	46,000	
	Gate house and miscellaneous		" "	10,000	
				605,510	
	Contingencies		20%	121,490	
				727,000	
	Engineering and overhead		15%	109,000	
	Total				$ 836,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission pole lines	10 mi.	Lump Sum	4,500	
	Contingencies		10%	500	
				5,000	
	Engineering and overhead		10%	500	
	Total				5,500
3.	Rights of Way and Land				
	Land	1,200 ac.	Lump Sum	58,000	
	Buildings purchased	50 sets	" "	140,000	
	Water rights, abandoned dam		" "	2,000	
				200,000	
	Legal, overhead, and general expense		20%	40,000	
	Total				240,000
4.	Highway Relocation				
	State highway, 20-ft. concrete	2.1 mi.	Lump Sum	158,500	
	State highway, 18-ft. tarvia	2.7 mi.	" "	128,700	
	Town road, 16-ft. gravel, bridge	0.4 mi.	" "	39,500	
				326,700	
	Contingencies		10%	33,300	
				360,000	
	Engineering and overhead		10%	36,000	
	Total				396,000
5.	Grand Total Capital Cost				$1,477,500
6.	Total Annual Cost				$ 86,000

(28) Perkinsville - No. 74.- (a) General.- The Perkinsville Reservoir, located on the Black River, Vermont, about 12.5 miles above the junction with the Connecticut, is outlined on Plate No. 138. Two dams are required, one at Perkinsville on the Black River, the other at Amsden on the North Branch of the Black River. The Perkinsville dam site is located about 0.3 mile north of Perkinsville. The Amsden dam site is located about 0.1 mile north of Amsden. The reservoir on the Black River extends upstream about 2.8 miles, and on the North Branch a similar distance. Most of the reservoir is in the Town of Wethersfield, Windsor County, Vermont; a small part is in Cavendish, Windsor County, Vermont. The 142 square miles of drainage area is hilly, mostly covered with woods and brush. As designed, the capacity is six inches of runoff from the watershed, or 46,200 acre-feet. The flooded area of 1,350 acres at the spillway crest, Elevation 635.0 m.s.l., is classified as follows:

(1) Tillage land 70%

(2) Pastureland 15%

(3) Wooded land 15%

(4) Towns, etc. .... Communities of Greenbush, Amsden, and Downers including 40 sets of buildings and one cemetery.

(b) Highways and roads.- About 4.7 miles of State Highway Route 106, consisting of 24-foot gravel, will be relocated; also, 3.0 miles of 28-foot, gravel, State Aid Road and 0.6 mile of 14-foot gravel connecting road will have to be built. The relocated road will include three large bridge structures. The general plan is indicated on Plate No. 138.

(c) Railroads.- None will be involved.

(d) Other public works.- Eight miles of telephone and transmission pole line will require relocation.

(c) Dams.- The general design of the dams, the area and capacity curves, and geological features are indicated on Plate No. 139.

(1) Geology.- At the Perkinsville site, on the Black River, rock outcrops above the terrace forming the left bank and underlies it at an unknown depth. Surface features indicate that rock rises beneath the right abutment, but this inference has not been verified by borings. An earth embankment constructed as a rolled fill is proposed with a tunnel conduit on the right bank. At the Amsden site, on North Branch, massive granite occurs throughout the right abutment. Similar rock, together with remnants of a fissured schist, crops out on the left bank. Two borings were drilled, which, together with the numerous surface exposures, showed rock to be at a maximum of about ten feet below the ground surface, and revealed a foundation condition entirely adequate for the concrete dam which is proposed.

(2) Available materials.- Suitable material for rolled-fill construction is available within 0.75 mile of the Perkinsville site. Rock for toe construction and riprap may be obtained from the tunnel excavation, supplemented by an additional quantity from boulders, accumulations and quarry stone. At the Amsden site, sand and gravel suitable for concrete aggregate are available on the right bank upstream within 0.5 mile. An alternative source of concrete aggregate is located downstream on the left bank within 0.2 mile.

(3) Dams and appurtenant works.- A rolled-fill earth dam is proposed at the Perkinsville site. The concrete spillway will be an ogee-section overflow dam, located at the Amsden site. The length of the earth-fill section is 2,540 feet, and the top elevation is 648 m.s.l., or 119 feet above the stream bed. This allows a freeboard of five feet above spillway-design flood. The spillway section

has a crest elevation of 635 m.s.l., about 52 feet above the stream bed.

(4) Dike.- Two dikes are required. Dike No. 1 is located about 2,000 feet southwest of the Amsden site. The dike has a top elevation of 648 m.s.l., and is 270 feet long. Dike No. 2 is located about 2,600 feet southeast of the Amsden site, has the same top elevation, and is about 270 feet long.

(5) Embankment.- The rolled fill of the earth dam will be 30 feet wide on top. It will consist of an impervious core from top to bottom, with side slopes of about 1 on 1-1/2. This core will be backed by a pervious section on both upstream and downstream faces, the outside slopes of which will be a minimum of 1 on 3 from the base to within 15 feet of the top, and 1 on 2-1/2 to the top. The upstream slope will be riprapped. The downstream slope will be sodded, with a rock-fill trench drain at the toe of the slope. An impervious blanket is provided on the upstream ground surface adjacent to the dam. The dikes are of similar construction to the main dam, but with a top width of 20 feet.

(6) Concrete spillway.- The concrete spillway section, 665 feet long, will be built entirely on rock. It is an ogee spillway section, operating with an 8-foot surcharge, and discharges directly into North Branch. At each end of the spillway section are short non-overflow sections. This surcharge of eight feet was adopted as the most economical because higher surcharges increased embankment cost, and lower surcharges were not feasible due to the limited width of the valley. The discharge capacity under an 8-foot surcharge is 51,500 second-feet, or the equivalent of 363 second-feet per square mile from the drainage area controlled.

(7) Outlet.- The normal flow of the Black River is

passed through a concrete-lined tunnel located on the right bank of the river at the Perkinsville site. The tunnel has an inside diameter of 12 feet. The elevation of the tunnel invert is 540 m.s.l. at the intake and falls on a uniform grade to 535 m.s.l. at the stilling basin. The length of the tunnel is 450 feet. Control is maintained by three 6-foot by 8-foot steel Broome gates. The discharge capacity at spillway elevation 635 is 5,880 c.f.s. The normal flow of North Branch is passed through an automatic outlet in the center of the spillway section. The elevation of the invert is 589 m.s.l. This separate conduit is required because the Amsden and Perkinsville reservoir areas are separated by ground at elevation 610, thus making it impossible to drain completely the Amsden reservoir through the Perkinsville outlet. No gates are provided at the Amsden outlet.

(8) Plan of construction.- It is planned to take two seasons to complete construction. The concrete spillway, main outlet, and dikes will be completed in the first season. Part of the fill of the Perkinsville dam will also be completed. The possibility of flood between seasons will make it necessary to leave the Black River channel open between seasons. Completed sections of embankment will be protected by impervious blankets and riprap on the open faces adjacent to the river.

(9) Conservation storage.- Additional storage for conservation to the extent of 9.6 inches of run-off or 71,800 acre-feet beyond that required for flood control can be developed at an additional cost of $5,383,000.

(Table on following page)

PERKINSVILLE - NO. 74

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	110 ac.	Lump Sum	$ 11,000	
	Stream control		" "	7,000	
	Excavation, earth	171,000 cy	$0.40	68,400	
	Excavation, rock	61,000 cy	2.30	140,300	
	Excavation, tunnel	4,500 cy	10.00	45,000	
	Embankment, rolled-fill	1,824,000 cy	0.45	820,800	
	Riprap, (hand-placed)	45,600 cy	3.00	136,800	
	Concrete, plain	24,000 cy	10.00	240,000	
	Concrete, reinforced	7,000 cy	12.00	84,000	
	Reinforcing steel	1,200,000 lbs.	0.06	72,000	
	Gates and machinery		Lump Sum	80,000	
	Gate house and miscellaneous		" "	10,000	
				1,715,300	
	Contingencies		20%	343,000	
				2,058,300	
	Engineering and overhead		15%	308,700	
	Total				$2,367,000
2.	Relocation of Railroads and Utilities				
	Telephone and transmission pole lines	8 mi.	Lump Sum	5,000	
	Contingencies		10%	500	
				5,500	
	Engineering and overhead		10%	500	
	Total				6,000
3.	Rights of Way and Land				
	Land	1,620 ac.	Lump Sum	60,000	
	Buildings purchased	40 sets	" "	150,000	
	Water rights		" "	10,000	
	Cemetery relocation	200 graves	" "	6,000	
				226,000	
	Legal, overhead and general expense		20%	45,000	
	Total				271,000
4.	Highway Relocation				
	24-foot gravel state highway	4.7 mi.	Lump Sum	353,500	
	Local gravel roads	3.6 mi	" "	283,000	
				636,500	
	Contingencies		10%	63,500	
				700,000	
	Engineering and overhead		10%	70,000	
	Total				770,000
5.	Grand Total Capital Cost				$3,414,000
6.	Total Annual Cost				$ 193,100

29. Hydeville - No. 60 - (a) General.- Hydeville Reservoir is outlined on Plate No. 115. The dam site is located on Millers River, 32.2 miles above the junction of the Millers and Connecticut Rivers, about 2.7 miles above the junction of Priest Brook and Millers River, and about 0.5 mile below a bridge, in the Township of Winchendon, Worcester County, Massachusetts. The drainage area of 85 square miles is mostly hilly, covered with second-growth timber and brush of little value. As proposed, the storage capacity, excluding a permanent pond at Elevation 840 m.s.l., covering 140 acres, will provide for about 3.2 inches of run-off from this watershed, or about 14,700 acre-feet. The flooded area up to the spillway crest, 875.0 m.s.l., will be about 850 acres, classified as follows:

(1)	Agricultural land	About 10%, including one nursery of 40 acres.
(2)	Pastureland	Included in (1) above.
(3)	Wooded land	90% of little value; mostly second-growth timber.
(4)	Towns, etc.,...........	The small Villages of Bullardville and Harrisville, as well as one sewage-disposal plant, owned by the Town of Winchendon, will be inundated.

(b) Highways and roads.- About 0.7 mile of local road will be raised above reservoir level. The improvement will be 14-foot gravel. Structures will be provided at river crossings. Other local roads in the reservoir will be abandoned.

(c) Railroads.- No railroads are located within the area.

(d) Other public works.- Seven miles of telephone pole line will be relocated.

(c) Dam.- A general design of the dam, the area and capacity curves, and the geological features are indicated on Plates Nos. 116 and 117.

(1) Geology.- Rock is deeply buried on the left side under pervious deposits of sand and gravel. The rock surface at the river lies about 50 feet below stream level, rises steeply under the right bank, and crops out above spillway elevation in a knoll on the far right side. Beyond, or west of the knoll, in a saddle valley, the rock surface is again obscured, but at bore hole 5 is situated at a depth of about 16 feet. A rolled-fill embankment is proposed. The spillway will be constructed on granite, in the saddle valley, and a conduit channel will be cut in similar rock for a portion of its length on the far right bank.

(2) Available materials.- Mixed deposits of sand and rock flour, suitable for the impervious section, are available upstream on the right bank within 0.5 mile. Sand and gravel for concrete aggregate and pervious-shoulder construction may be obtained downstream within 0.5 mile. Boulders, culled from borrow areas, and rock from rock excavations, will be available for riprap and rock toes.

(3) Dam and appurtenant works.- The dam will consist of a rolled-earth fill divided into three sections, which are the main dam, a low dike, and a small dam containing the spillway. The main dam extends from a point on the slope of the left bank, and crosses the river at a right angle to a high point on the right bank. This embankment will be about 3,200 feet long. The high section of the dam at the river will be about 400 feet long, and will have a maximum height of 65 feet, the remaining 2,800 feet being about 15 feet high. Separated

from this dam by high ground is a low dike about 400 feet long. The spillway is built into a small dam across a gully, which is separated from the main dam and dike by high ground. This section will be about 910 feet long, the concrete spillway, including the gate section, being 180 feet long, and the earth fill 730 feet long. The top elevation of the embankments is 890 m.s.l., or about 65 feet above stream bed, and will allow a freeboard of about five feet above maximum flood.

(4) Alternate.- No alternate plan is proposed.

(5) Embankment.- The rolled-fill earth embankment containing the spillway will be 20 feet, the dike ten feet, and the main dam 25 feet wide on top. The dams will consist of an impervious core from top to bottom, with the sides sloping 1 on 1-1/4 keyed into the ground with a cut-off section along the axis of the dam. An impervious blanket will be provided, extending from the downstream toe of the impervious core upstream for a distance of ten times the height of the spillway above the base of the earth section. The impervious core will be backed with a pervious section on both faces. On the upstream side this pervious section will have an outside slope of 1 on 3 from the bottom to within 15 feet from the top and 1 on 2-1/2 for the remaining 15 feet for the entire length of the dams. This slope will be provided with hand-placed riprap. On the downstream side at the stream crossing the pervious section will have the same outside slopes as the upstream side for a distance of about 400 feet, but a 10-foot-wide berm will be provided at an elevation of 15 feet from the top. A rock-fill trench at the toe will provide for drainage. The remaining part of the downstream side of the dams will have an outside slope of 1 on 3-1/2 from top to bottom. A gravel-fill trench at the toe will provide

for drainage. The low 400-foot-long dike is similar in section to the low sections of the dam except that no cut-off is provided. The entire amount of impervious material for the embankment will be obtained from borrow. As much of the spoil from the outlet and spillway excavation as is suitable will be used as pervious material.

(6) Spillway.- A 170-foot spillway weir will be constructed in the dam across a gully on the right bank. With the crest at 875 m.s.l., and a 10-foot surcharge, the discharge capacity will be 19,650 c.f.s., or 231 second-feet per square mile from the watershed controlled. Concrete abutment walls separate the spillway from the earth sections. The spillway discharges into a channel paved with concrete for a distance of about 25 feet beyond the toe of the spillway apron, and retaining walls extend 125 feet beyond the channel paving. A wide excavation below the spillway and a natural gully carry the discharge into the Millers River at a point about 1,200 feet downstream from the center-line of the main dam. The total length of the spillway discharge channel is about 2,800 feet.

(7) Outlet.- An open channel, ten feet wide, passing through the dam at the right end of the spillway, will provide stream-control during construction and reservoir-control later. The discharge capacity under the maximum operating head (spillway crest) will be 8,250 second-feet. At the center-line of the dam a gate section will be provided, which will include one 10 by 35-foot Stoney gate, mechanically controlled by operating machinery mounted directly above on the gate structure. The bottom elevation of the outlet channel will be 840 m.s.l. This will cause the creation of a permanent pond covering approximately 140 acres.

(8) Plan of construction.- It is proposed, first, to construct the outlet, including the right abutment, clear the ground for the permanent pond, and prepare the ground for the embankment. The stream will then be diverted through the outlet and the embankments completed. Finally, the spillway weir and gate structure will be constructed and the gate installed. It is estimated that a construction period of about seven months will be required, or one working season.

(9) Conservation storage.- Not feasible. A higher dam at this site will inundate part of Waterville and the cost will be prohibitive.

(Table on following page)

HYDEVILLE - NO. 60

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	600 ac.	Lump Sum	$ 45,000	
	Stream control		" "	8,000	
	Excavation, earth	148,000 cy	$0.40	59,200	
	Excavation, rock	5,000 cy	3.00	15,000	
	Embankment, rolled-fill	307,000 cy	0.45	138,150	
	Riprap, (hand placed)	14,400 cy	3.00	43,200	
	Concrete, plain	10,700 cy	10.00	107,000	
	Gates and machinery		Lump Sum	10,000	
	Gate house and miscellaneous		" "	12,000	
				437,550	
	Contingencies		20%	87,450	
				525,000	
	Engineering and overhead		15%	79,000	
	Total				$604,000
2.	Relocation of Railroads and Utilities				
	Telephone lines	7 mi.	Lump Sum	3,000	
	Contingencies		10%	300	
				3,300	
	Engineering and overhead		10%	300	
	Total				$ 3,600
3.	Rights of Way and Land				
	Land	900 ac.	Lump Sum	18,700	
	Buildings purchased	10 sets	" "	16,000	
	Water rights		" "	2,000	
	Sewage treatment plant		" "	60,000	
				96,700	
	Legal, overhead, and general expense		20%	19,300	
	Total				$116,000
4.	Highway Relocation				
	14-ft. gravel surfaced local road	0.7 mi.	Lump Sum	19,900	
	Contingencies		10%	2,000	
				21,900	
	Engineering and overhead		10%	2,100	
	Total				$ 24,000
5.	Grand Total Capital Cost				$747,600
6.	Total Annual Cost				$ 44,100

(30) Priest Pond - No. 61A.- (a) General.- The Priest Pond reservoir, on Priest Brook, Mass., about 3.1 miles above its junction with the Millers River, is outlined on Plate No. 118. The dam site is located about 2.2 miles northwest of New Boston and about 1,500 feet downstream from a highway bridge crossing Priest Brook. The reservoir extends upstream about 3 miles, all but a small section in the Towns of Royalston and Winchendon in Worcester County, in the State of Massachusetts. A small part of the reservoir is in the Town of Fitzwilliam, in Cheshire County, in the State of New Hampshire. The drainage area of 18.8 square miles is hilly, mostly woods and brush of little value. As designed, the capacity is 6.0 inches of run-off from the watershed above, or 6,000 acre-feet. The flooded area of 500 acres at the spillway crest elevation, 879.0 m.s.l., is classified as follows:

(1) Agricultural land 10%

(2) Pastureland 10%

(3) Wooded land, mostly brush and second growth 80%

(4) Towns, etc. .... none.

(b) Highways and roads.- About 2-1/2 miles of local gravel road, 18 feet wide will have to be built. A tentative relocation is sketched on the reservoir map, Plate No. 118.

(c) Railroads.- None will be involved.

(d) Other public works.- None would be involved.

(e) Dam.- The general design of the dam, the area capacity curves, and geological features are indicated on Plates Nos. 119 and 120.

(1) Geology.- The site finally selected for purposes of design and estimates is situated about 750 feet downstream from that originally investigated. The geological conditions at the downstream site are fully as good as, if not better than, those disclosed by borings at the upstream site. The lowest point in the rock floor is situated east of, and at a depth of, about 40 feet below the brook. The rock surface on the left side rises beneath a pervious overburden, composed chiefly of sand, which becomes less pervious on the right side by reason of an increase in the rock-flour content. An earthen embankment, constructed as rolled-fill, is proposed. The spillway and outlet conduit will be constructed in rock on the right side.

(2) Available materials.- Sand and rock-flour are available for the impervious sections in the higher ground on the right bank within 0.5 mile. Sand and gravel, suitable for pervious embankment and concrete aggregate, are also available on the right bank within 0.5 mile. Processing of concrete aggregate by screening and washing is desirable. Materials for riprap and rock toes may be obtained from rock excavations, and a supplementary volume from boulder accumulations.

(3) Dam and appurtenant works.- A rolled-fill earth dam is proposed for this site. The spillway will be located in rock on the right bank, adjacent to the end of the dam, and separated from it by a retaining wall and Tainter gate. The length of the earth fill section is 1,615 feet. The top elevation is 893 m.s.l., or about 44 feet above the stream bed. This will allow for a freeboard of 5 feet above the maximum or spillway-design flood.

(4) Alternate.- A reservoir having a 24" run-off capacity for flood control and power storage is also being considered.

(5) Embankment.- The rolled-fill of the earth dam will be 20 feet wide on top. It will consist of an impervious core from top to bottom, with side slopes of 1 on 1-1/2. This core will be backed by a pervious section on both up and downstream faces, the outside slope of which will be a minimum of 1 on 3 up to 15 feet below the top of the dam. From there to the top the slopes will be 1 on 2-1/2 as a minimum. The upstream slope will be paved with riprap, 2-1/2 feet thick. The downstream slope will be covered with loose rock and a rock-filled trench will be provided along the downstream toe to insure drainage. An earth blanket will be provided over the pervious section of the reservoir bottom, adjacent to the dam. Most of the materials for the embankment will be obtained from spoil from the outlet and spillway excavation.

(6) Spillway.- An open-ogee section, concrete spillway 55 feet long will be constructed on ledge rock. The discharge will be carried through a spillway cut, partly in rock, around the right end of the dam. It will be returned to the main stream about 700 feet below the toe of the dam. The discharge capacity under a 9 foot surcharge is 4,000 second-feet, or the equivalent of 212 second-feet per square mile from the drainage area controlled. The freeboard of 5 feet will be above this 9-foot surcharge. No control will be provided. The spillway discharge is returned to the main stream a sufficient distance downstream so that no damage will occur to the toe of the dam.

(7) Outlet.- An open intake channel 900 feet long will be provided for the outlet. This will be partly in rock cut. A Tainter gate will be provided in a reinforced concrete section between the spillway and the abutment. The discharge will pass through an outlet channel, excavated partly in rock, 1,100 feet long, returning to the river 700 feet below the toe of the dam. The discharge capacity under maximum head, spillway crest elevation, is 1,010 c.f.s.

(8) Plan of Construction.- It is proposed to prepare the foundation for the earth dam first, and then as the excavation for the outlet and spillway channel progresses, build the ends, letting the stream remain in its normal bed. When the outlet is completed, a dike will be constructed across the stream to divert it to this outlet channel. Then the center section of the earth dam will be completed. The construction period will be about 7 months.

(9) Conservation storage.- Conservation storage to the extent of 18 inches of run-off, or 18,000 acre-feet, in addition to the flood-control storage is feasible at an additional cost of $685,300, making the total cost of the development $1,107,400.

(Table on following page.)

PRIEST POND - NO. 61A

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Clearing	240 ac.	Lump Sum	$ 20,000	
	Stream control		" "	2,000	
	Excavation, earth	129,000 c.y.	$0.40	51,600	
	Excavation, rock	8,000 c.y.	3.00	24,000	
	Embankment, rolled-fill	141,000 c.y.	0.30	42,300	
	Riprap	8,900 c.y.	1.50	13,350	
	Concrete, plain	3,600 c.y.	12.00	43,200	
	Concrete, reinforced	1,600 c.y.	14.00	22,400	
	Reinforcing steel	160,000 lbs.	0.06	9,600	
	Gates and machinery		Lump Sum	5,000	
	Miscellaneous		" "	2,000	
				235,450	
	Contingencies		20%	47,050	
				282,500	
	Engineering and overhead		15%	42,500	
	Total				$325,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	600 ac.	Lump Sum	12,000	
	Buildings purchased	2 sets	" "	6,000	
				18,000	
	Legal, overhead and general expense		20%	3,600	
	Total				21,600
4.	Highway Relocation				
	Town roads, gravel	2.5 mi.	Lump Sum	62,400	
	Contingencies		10%	6,200	
				68,600	
	Engineering and overhead		10%	6,900	
	Total				75,500
5.	Grand Total Capital Cost				$422,100
6.	Total Annual Cost				$ 27,300

SUMMARY OF DETAILS OF DAMS.

9. The following Table 50 lists the various reservoirs in the Comprehensive Plan and the alternate reservoirs and gives the principal dimensions for the structures, the quantities of earth embankment, concrete and rock excavation, and the construction cost for each.

(Table on following page.)

TABLE 50

SUMMARY OF DETAILS OF DAMS

Index No.	Reservoir	Control	Type	Height Above Stream Bed Feet	Length of Dam Feet	Type of Spillway	Spillway Length Feet	Conduit Length Feet	Conduit Area Sq. Ft.	Earth Embankment Cubic Yds.	Concrete Cubic Yds.	Rock Excavation Cubic Yds.	Total Construction Cost
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
						RESERVOIRS OF COMPREHENSIVE PLAN							
18A	East Haven	Retarding	Earth	103	2,030	Side-hill	110	610	72	1,175,000	11,300	82,500	$1,189,000
21A	Lyndon Center	Retarding	Earth	79	2,625	Saddle	205	410	50	670,000	5,500	5,200	776,000
22A	Victory	Retarding	Earth	46	535	Side-hill	75	220	58	55,000	11,400	-	367,000
50	Harvey Lake	Retarding	Earth	32	730	Saddle	300	150	63	36,000	5,700	-	163,000
24A	Bethlehem Junction	Retarding	Earth	163	2,030	Side-channel	155	1,310	100	1,620,000	19,200	35,200	2,146,700
27A	Groton Pond	Retarding	Rock-fill & Concrete	19	1,090	Overflow Section	200	12.5	30	6,500	2,350	400	65,000
28A	South Branch	Retarding	Earth	95	810	Morning-glory	108	560	72	290,000	8,100	4,200	489,000
48	Union Village	Gates	Earth	155	915	Morning-glory	320	450	152	1,008,000	19,000	56,000	1,726,000
29A	Gaysville	Gates	Concrete-Arch	170	875	Overflow Section	300	55	32	103,000	97,700	17,000	1,603,000
30A	Ayers Brook	Retarding	Earth	70	2,640	Side-channel	125	330	37	191,000	3,900	50,000	393,000
49A	South Tunbridge	Gates	Earth	88	1,040	Side-Channel	320	440	167	452,000	14,800	130,000	1,005,000
63	North Hartland	Gates	Earth	153	1,425	Side-channel	645	730	226	1,632,000	30,000	321,000	2,704,000
64A	Claremont	Gates	Earth	105	2,120	Side-channel	520	475	238	1,746,000	32,900	280,000	2,571,000
55A	North Springfield	Gates	Earth & Concrete	83	1,100	Side-hill	398	41	225	360,000	25,100	23,000	1,057,000
40A	Newfane	Gates	Earth	131	1,850	Side-channel	700	1,020	212	2,224,000	32,200	362,000	3,240,000
57A	Surry Mountain	Gates	Earth	76	1,630	Side-channel	305	480	120	786,000	15,300	133,000	1,295,000
59	Lower Naukeag	Gates	Earth	30	470	Overflow Section	180	20	49	147,000	4,600	1,800	298,000
65	Birch Hill	Gates	Earth	59	1,776	Side-hill	175	-	-	388,000	11,600	61,400	845,000
62A	Tully	Gates	Earth	65	1,050	Saddle	180	320	50	212,000	4,500	10,000	423,000
47	Knightville	Gates	Earth	140	1,475	Saddle	435	650	216	1,002,000	19,600	22,200	1,364,000
						ALTERNATE RESERVOIRS							
26	Gale River	Retarding	Rock-fill	92	630	Side-channel	290	530	144	313,000	10,500	144,900	833,000
69	Bath	Retarding	Earth	160	950	Side-channel	400	870	300	1,144,000	26,600	168,800	1,874,000
70	Centerville	Gates	Earth & Concrete	165	1,420	Overflow Section	310	64	454	826,000	229,800	15,000	4,026,000
66	West Canaan	Gates	Concrete	53	610	Overflow Section	270	44	96	-	16,900	9,500	411,000
72	Mascoma Lake	Gates	Earth & Concrete	40	920	Overflow Section	170	30	192	42,000	11,800	6,500	361,000
53A	Stocker Pond	Retarding	Earth	48	415	Side-hill	55	230	42	67,000	3,400	12,000	202,000
36	Ludlow	Gates	Earth	82	570	Side-channel	172	290	98	315,000	9,900	124,000	836,000
74	Perkinsville	Gates	Earth & Concrete	119	2,540	Overflow Section	665	450	113	1,824,000	31,000	65,500	2,367,000
60	Hydeville	Gates	Earth	65	4,110	Overflow Section	180	-	-	307,000	10,700	5,000	604,000
61A	Priest Pond	Gates	Earth	44	1,615	Side-hill	55	-	-	141,000	5,200	8,000	325,000

RESERVOIR SITES STUDIED

10. Plate No. 153 shows 58 storage reservoir sites that have been studied in connection with this report. A number of other sites have been considered, with preliminary estimates, and were dropped as not feasible. Most of these sites were of those considered for the 308 Report.

11. Twenty reservoirs are recommended for the Comprehensive Flood Control Plan and ten others are offered for consideration as alternates or substitutes in the event of difficulties in acquiring land for the reservoir sites in the recommended group or for the provision of additional storage for flood control or for recreation, power and sanitation. These sites are fully described in the main body of the report; the detailed descriptions and estimates are found in this Appendix.

12. The following 14 sites were shown as part of the Comprehensive Flood Control Plan suggested in the 308 Report, House Document No. 412, 74th Congress, 2d Session. The ten first of these are located above Fifteen Mile Falls and were eliminated from inclusion in this report owing to the fact that the area above Fifteen Mile Falls does not contribute to major flood peaks, and their primary value would be for power storage and not for flood control.

13. The four sites numbered 23, 19, 25 and 31 were reestimated and studied, and found less desirable and economical than the other sites recommended:

No.	Reservoir	Stream
11	Happy Corner	Perry Stream
1	Pittsburg	Connecticut
12	Perry Brook	Indian Stream
13	Kim Day	Indian Stream
2	Indian Stream	Connecticut
14	Kidderville	Hicks Brook (Mohawk)
15	Bog Dam	Upper Ammonoosuc
16	Phillips Bog	Phillips Brook (Upper Ammonoosuc)
17	Jefferson	Israel
6	Upper Fifteen Mile Falls	Connecticut
23	Kaiser Pond	Joes Brook
19	East Burke	Passumpsic
25	Alder Brook	Ammonoosuc
31	North Randolph	White River

14. In Table 51, following, are shown 14 sites that were studied in detail for the report. In computing the economic justification for the Comprehensive Plan, it was not found possible to include these reservoirs, several of which have definite merit and may be useful as compromise reservoirs for specific protection for certain rivers. Sugar Hill, No. 68, for instance, controls 246 square miles of the Ammonoosuc River, and would afford valuable protection for that stream, particularly if difficulties should develop regarding Bethlehem Junction, No. 24A, in the recommended Group or for Gale River, No. 26, and Bath, No. 69, in the Alternate Group. South Randolph, No. 52, and North Royalton, No. 71, would give additional and reasonably economical protection for the White River.

TABLE 51
SUMMARY OF OTHER SITES STUDIED

IDENTIFICATION NO.	NAME OF RESERVOIR	STREAM	DRAINAGE AREA SQUARE MILES: GROSS	DRAINAGE AREA SQUARE MILES: NET	CAPACITY: ACRE-FEET	CAPACITY: INCHES OF RUN-OFF	AREA AT SPILLWAY CREST (ACRES)	COST TO UNITED STATES	COST TO LOCAL INTERESTS	TOTAL COST	COST PER ACRE-FOOT	COST PER SQ. MI. (NET DRAINAGE AREA)	TOTAL ANNUAL COST
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
20	LYNDONVILLE	PASSUMPSIC RIVER...........VT.	70	70	8,000	2.1	260	$ 930,000	$ 220,400	$1,150,400	$ 144	$ 16,400	$ 62,600
51	FRANCONIA [illegible]	HAM BR.-GALE RIVER (AMMONOOSUC RIVER)...N.H.	30	30	9,600	6.0	570	631,000	250,400	881,400	92	29,400	50,600
68	SUGAR HILL	AMMONOOSUC RIVER...........N.H.	246	246	78,800	6.0	1,620	2,878,500	2,878,500	5,757,000	73	23,400	319,100
52	SOUTH RANDOLPH	SECOND BRANCH (WHITE)......VT.	63	63	16,000	4.8	550	636,000	611,900	1,247,900	78	19,800	72,900
71	NORTH ROYALTON	SECOND BRANCH (WHITE)......VT.	72	72	23,200	6.0	940	685,000	685,000	1,370,000	59	19,000	81,800
67	HARTFORD	WHITE RIVER.................VT.	704	704	121,500	3.2	2,530	4,213,500	4,213,500	8,427,000	69	12,000	492,100
35A	BRIDGEWATER COR.	OTTAUQUECHEE RIVER.........VT.	101	101	32,400	6.0	740	1,809,000	1,014,000	2,823,000	87	28,000	160,000
54	CROYDON	CROYDON BRANCH (SUGAR)....N.H.	55	55	6,600	2.3	410	338,000	237,400	575,400	87	10,500	33,200
73	SPECTACLE POND	CROYDON BRANCH (SUGAR)....N.H.	65	65	20,500	5.9	720	623,300	623,300	1,246,600	61	19,200	70,800
37A	AMSDEN	NORTH BRANCH (BLACK).......VT.	27	27	8,700	6.0	640	263,100	263,100	526,200	60	19,500	31,800
56A	CAMBRIDGEPORT	SAXTONS RIVER..............VT.	58	58	18,600	6.0	610	1,410,000	581,000	1,991,000	107	34,300	115,400
38	THE ISLAND	WEST RIVER..................VT.	40.9	40.9	13,100	6.0	620	814,000	227,600	1,041,600	79	25,400	61,300
39	NORTH LANDGROVE	ORCUTT BROOK (WEST)........VT.	21.3	21.3	6,800	6.0	295	403,500	150,700	554,200	81	26,000	36,100
58	OTTER BROOK	OTTER BROOK (ASHUELOT)....N.H.	46.7	46.7	13,800	5.5	330	1,159,000	243,200	1,402,200	102	30,000	78,300

FLOOD CONTROL

CONNECTICUT RIVER VALLEY

REPORT OF SURVEY

AND

COMPREHENSIVE PLAN

DETAILS AND ESTIMATES OF

DIKES

SECTION 5 OF THE APPENDIX

VOLUME 2

EXISTING DIKES

1. Dikes for protection from floods have been constructed by various interests in the lower Connecticut River since the middle of the nineteenth century. There are no protective dikes in the upper valley, in the States of New Hampshire and Vermont. The dikes constructed to protect rural areas are principally to prevent erosion. Dikes constructed to protect real estate and industrial developments were constructed, in general, to give protection against a flood of the magnitude of 1854, which, in the lower valley, was approximately the same height as the more recent flood of 1927. In view of the all time record flood of 1936, which topped all existing dikes and caused great losses, a number of existing dikes are being raised and enlarged by the Engineer Department, with local cooperation, as work relief projects in accordance with the Flood Control Act of 1936. Detailed information pertaining to existing dike protection is given in the following table:

(Table on following page)

TABLE NO. 52
EXISTING DIKES ALONG THE CONNECTICUT RIVER

Location	Character of Work	Approx. Elev. of Protection (M.S.L.)	Approx. Elev. of 1936 Flood (M.S.L.)	Length of Dike (Ft.)	By Whom Built	Dates of Projects	Protected Area: Approx. Acres	Protected Area: Character of Area	Construction of Works: Construction by Others	Construction of Works: U.S.E.D. in 1936-37	Construction of Works: Total
Hatfield	Earth Dike	129.0	131.0	1,600	State	1903-05	---	3,5	$ 6,700	$ -----	$ 6,700
	Earth Dike	129.0	131.0	2,100	State	1913-14	---	3,5	6,500	-----	6,500
	Earth Dike	129.0	131.2	2,300	State	1928-29	---	3,5	36,300	-----	36,300
	Earth Dike	129.0	130.8	3,[illegible]	Town	1933-34	---	3,5	13,000	-----	13,000
	Earth Dike	129.0	131.0	2,600	State	1936	---	3,5	11,000*	-----	11,000
	Earth Dike ø	134.0	134.5	1,240	U.S.E.D.	1936	---	3,5	------	42,000*	42,000
Hadley	Earth Dike	125.0*	129.6	1,093	State	1902	---	2,3,5	4,800	-----	4,800
	Earth Dike	130.0	130.7	1,545	State	1928-29	---	2,3,5	6,200	-----	6,200
	Earth Dike	130.0	130.8	350	State	1933-34	---	2,3,5	3,200	-----	3,200
	Earth Dike	130.0	130.6	3,700	State	1936	---	2,3,5	12,000*	-----	12,000
	Earth Dike ø	130.0	130.7	2,900	U.S.E.D.	1936	---	2,3,5	-----	41,500*	41,500
Northampton	Earth Dike	123.0	129.0	2,000	Private	1856-69	100	1,2,3,4	7,500*	-----	7,500
South Hadley	Concrete Wall	76.5	75.0	1,700	State	1936	30	2,4	28,000*	-----	28,000
Holyoke	Earth Dike	58.0	70.7	140	State	1915-16	75	5	1,200*	-----	1,200
	Earth Dike	66.0	72.4	4,285	City	1928-31	130	1,3,6	109,300	-----	109,300
	Pumping Plant	---	---	-----	City	1928-31	---	---	13,200	-----	13,200
	Raising Dike ø	73.0	72.4	5,890	City	1936-	125	1,3,6	101,900*	-----	101,900
Chicopee	Earth Dike ø	64.5	70.3	8,000	City	1936-	250	1,3,4,5	30,000*	-----	30,000
Springfield	Earth Dike	63.0-64.0	66.0-67.0	6,200	City	1928	150	1,2,3,4	35,000	-----	35,000
	3 Pumping Plants	---	---	---	City	1927-28	---	---	300,000	-----	300,000
	Raising Dike ø	67.4-69.3	66.0-67.9	9,000	U.S.E.D.	1936-	400	1,2,3,4	---	75,000*	75,000
W. Springfield	Earth Dike	62.0	65.5	11,500	Private	1917-18	1600	1,2,3,4,6	45,000	-----	45,000
	Earth Dike ø	66.4-67.3	66.1-67.0	6,070	U.S.E.D.	1936-	2000	1,2,3,4,6	---	100,000*	100,000
Agawam	Earth Dike	50.0*	62.3	450	State	1913	50	5	1,000*	---	1,000
Hartford	Earth Dike	32.0	37.0	9,500	Private	1852-57	250	6	125,000*	---	125,000
	Earth Dike	33.5	36.1-36.7	15,500	City	1929-30	1200	1,2,3,4,5,6	1,151,000	---	1,151,000
	Pumping Plant	---	---	---	City	1929-30	---	---	150,000	---	150,000
	Raising Dike ø	36.2-36.9	36.1-36.9	17,400	U.S.E.D.	1936-	1500	1,2,3,4,5,6	-----	166,000*	166,000
					TOTAL				$2,197,800	$424,500	$2,622,300

* Estimated
ø Under Construction

1. Manufacturing and Industrial
2. Business
3. Residential
4. Municipal and Civic
5. Farming
6. Undeveloped

GENERAL DATA ON DIKES

2. Data available for design.- Preliminary topographic maps and cross sections obtained from surveys of the proposed dike locations, supplemented by maps of the protected areas obtained from local sources, have been used as a basis for preliminary design. Foundation test pits, auger and core borings have been taken for preliminary investigation of foundation conditions. Soil samples have been examined in the Soils Laboratory to determine suitability of the materials for embankment construction and to determine the permeability of soils and expected seepage through and under the dikes where seepage is an important consideration in design. The foundation explorations and investigations of the materials have been sufficient to permit determination of safe and economical preliminary dike design.

3. Design grade.- The elevations to which the dikes have been designed have been based upon the greatest predicted flood, as modified by the Comprehensive Plan of twenty reservoirs, plus a design freeboard of approximately three feet, based upon the fetch of the riverside slope of the dike, and the velocity head of the maximum expected waves.

4. Basis of estimates.- (A) The costs of the dikes have been estimated upon the basis of a design which will provide the most economical and safe construction for the particular site. Earth dikes of 10-foot crown width and side slopes not steeper than 1 vertical on 2 horizontal are provided, except where lack of space precludes their use, in which case reinforced concrete flood walls of the cantilever type are generally used. River banks and earth fills, where subject to scour by ice action or high velocities, are protected by riprap paving. Steel sheet pile cut-off walls are provided under concrete walls and earth fills that may be subject to high heads and which are constructed on

permeable foundations that will permit a relatively large amount of seepage. Subsurface filter drains are proposed at the landside toe of high earth sections to insure adequate stability of the soil structure by maintaining a low saturation line, and at the landside toe of all concrete walls to prevent piping.

(b) In the design of facilities to provide adequate drainage of the protected areas during flood stages of the Connecticut River, the capacities of the pumping plants and drainage systems have been based upon the following factors: amount of rainfall, intensity, and duration of storms; sanitary sewage based upon population intensity; seepage through and under the dike; size of storage basins, if any.

5. Cooperation with other local projects.- In all cases effort has been made to determine plans for future construction works under consideration by local interests in order that any proposed dike construction can be adapted to a local improvement program as long as the Federal expenditure for flood control is not increased and the integrity of the dike construction is protected.

6. Unit prices.- Unit prices are based upon construction costs for similar types of work in New England and elsewhere, particular use being made of data on various existing dikes, drainage and pumping systems in the Connecticut Valley. Unit prices vary with the conditions, type and method of construction and the availability and location of materials at each site. The fact that the general construction cost index has advanced almost to the 1927-29 level has made it desirable to compare with prices current on similar work performed at that time.

7. Contingencies, engineering, and overhead.- Contingencies are estimated at 20 per cent on account of the preliminary character of the survey data and foundation explorations, the location and design of the dike, and the construction difficulties anticipated. Engineering and

overhead costs are estimated at 15 per cent of the construction costs.

8. Rights of way and damages.- The estimates of costs of rights of way and the estimated damages which will accrue on account of the acquisition of lands and construction of dikes are based upon information from local officials, upon assessed valuations, and upon field reconnaissance in accordance with generally accepted appraisal methods. Under the state laws properties are assessed at their fair market values, based on appraisals made every ten years. Damages to riparian rights have been classed as damages since the disposition of the rights by the individual owners can not be foretold prior to acquisition of rights of way. A factor estimated at 20 per cent has been added for legal and acquisition costs and general contingencies.

9. Basis of annual costs.- Construction costs and all other capital costs arising from the proposed works have been reduced to annual carrying charges. The Federal investment includes only estimated construction cost of the dikes. Interest during construction has been added to the construction cost of the dikes where the time of construction exceeds one construction season, the rate being 4 per cent and 5 per cent respectively, for Federal and non-Federal costs. The non-Federal investment includes the value of land and rights of way, and the construction costs of pumping and drainage facilities. The total capital Federal costs thus arrived at have been amortized over a period of 50 years at 4 per cent, capital non-Federal costs have been amortized over a period of 50 years for pumping plant buildings and sewers, and 20 years for pumping machinery and appurtenant equipment, at 5 per cent. Interest on investment has been computed at 4 per cent and 5 per cent respectively for Federal and non-Federal investments. Loss of taxes on lands and property transferred to municipal ownership has been computed as a non-Federal cost. Maintenance and operation have been included in

the non-Federal annual costs and, in general, are equal to about two per cent of the total capital costs of the drainage and pumping facilities and about one-half of one per cent of the total dike construction costs.

10. Hartford, Connecticut.

a. Description of the City.- Hartford, the capital of the State of Connecticut, is situated on the west bank of the Connecticut River 52 miles above its mouth and at the head of the 15-foot navigation project. It covers an area of 17.4 square miles and had a population of 164,072 in the 1930 census. The principal business activities are the manufacture of various products, particularly machine tools, brushes, and firearms. It is an important railroad terminal and tobacco warehousing center. It is the home office of several insurance companies and is often referred to as the insurance center of the United States.

b. Description of flooded area.- The sections of the city subject to floods are the low plains along the river, which vary in width from about 1,500 feet at the center of the town to about 6,000 feet at the city limits, and an area of about 70 acres in the heart of the city which is inundated by the backwaters of the Park River. The development in the low area along the Connecticut River is principally factories and storage warehouses. A large railroad classification yard is also in this area. The 1936 flood overtopped the Clark and Colt Dikes, flooding the important industrial area and the municipal airport. The area flooded by backwater up the Park River contains commercial buildings, hotels and retail business establishments.

c. Existing dikes.- The "Colt" and "Clark" Dikes are in the southern portion of the city. The Colt Dike was constructed soon after the great flood of 1854 by Colonel Samuel Colt to protect the Colt Firearms Company. The top of the dike has an elevation of about 31 feet above mean sea level and is used as a roadway. The Clark Dike was constructed by the City of Hartford in 1930-1931 to protect an area known as the South Meadows in the southern end of the city. The dike is constructed principally of river sand with a relatively impervious outer section and has a steel sheet pile cut-off wall through the pervious foundation. The riverside slope is protected with riprap to approximately 25 feet above mean sea level. The Colt dike does not have a cut-off wall and subsequent investigations indicate that the soil in the area protected is sufficiently impervious to prevent sand boils during floods. The Clark dike and a portion of the Colt dike along the Connecticut River are being raised to the Comprehensive Plan design grade by the Engineer Department, as a work relief project of the Works Progress Administration.

d. Flood losses.- The amount of direct losses sustained during floods prior to 1936 is not available. The direct losses within the protected area sustained during the 1936 flood amounted to $7,330,000, of which $2,245,000 was urban, $4,565,000 industrial, $450,000 highway, and $70,000 railway. From the frequency-damage relationship an annual direct loss of $141,400 is obtained. (See Report, Paragraph 45). The indirect losses attributable to the flood, such as loss of business, loss of employment and interruption of transportation and communication, with their consequent interference with regular activities are slightly more than the direct losses. There has also been a decrease in the value of flooded property which is not reflected by the computation of the direct and indirect losses. The recoverable capital loss because of the 1936 flood is approximately 80 per cent of the total capital loss of $34,100,000, and amounts to $27,280,000. Estimating a conservative yield of 6.0 per cent the average annual loss, because of the reduction from normal values, is $1,640,000. The average annual losses which are prevented by the proposed plan of dike protection are summarized in the following table, the direct and indirect losses having been reduced by the amount preventable by the Comprehensive Plan of reservoirs:

Annual Direct Loss	$29,300	
Annual Indirect Loss	$32,200	
Annual Loss from Decrease in Property Values	$1,640,000	
Total Annual Loss		$1,701,500

PLAN OF PROTECTION

e. Alignment.- The Plan of Protection includes the raising of the Clark Dike and about 2,000 feet of the Colt Dike to the Comprehensive Plan design grade which is now being executed by the Engineer Department as a work relief project. The balance of the protection along the Connecticut River consists of a combination of earth dike and concrete flood wall, just east of the New York, New Haven and Hartford Railroad tracks, from the Colt Dike to high ground near the Memorial Bridge. Free flow of the Park River will be provided by a reinforced concrete conduit through the dike. The dike begins again just north of the Memorial Bridge and parallels the Connecticut River for about 14,000 feet and continues in a westerly direction across the railroad tracks to high ground just east of Main Street as indicated on Plate Number 141. Meadow Brook, in the North Meadows, will be diverted outside of the dike. Concrete walls will extend upstream on both sides of the Park River from the conduit at Connecticut River to Hudson Street on the east side of Bushnell Park. The concrete wall will continue along the north boundary of the park to the railroad embankment. This wall will allow Park River to overflow its banks in the park but will prevent the overflow from spilling into the protected area. A low earth dike along the south boundary of the park will perform a similar function. The proposed construction is indicated on Plate Number 144.

f. Subsurface investigations.- The North and South Meadows are rolling alluvial plans sloping gently away from the river so that the drainage is collected in the low areas to the west. The investigations made prior to the construction of the Clark Dike in the South Meadows as shown on Plate Number 143 indicated that the relatively impervious silty sand stratum was underlain with a pervious sand stratum and made the construction of a sheet pile cut-off wall advisable under the dike. Subsurface samples taken with augers and core drills in the North Meadows as shown on Plate Number 142 indicate that there is in general a 10 to 20 foot thickness of relatively impervious silty sand stratum underlain with a pervious sand stratum along the river; however, borings taken in the low area 2,000 and 3,000 feet from the river indicate that the silty sand is quite thin and that water from the sand stratum would probably boil through it in times of great flood unless it is cut off with steel sheet piling under the dike.

g. Embankment.- The earth embankment will be subjected to a head of about 20 feet in a great flood. The earth section is designed with a crown width of 10 feet and side slopes of 1 vertical on 2.5 horizontal. North of the New York, New Haven and Hartford Railroad bridge the material used will be silty sand obtained along the river bank adjacent to the dike. The fill for the remainder of the earth section will be obtained from the North and South Meadows and hauled to the site in trucks. The embankment will be well compacted and provided with a pervious blanket and gravel drain on the landside to lower the saturation line in the dike during floods. A steel sheet pile cut-off is proposed under the entire length of the dike.

h. Concrete walls and stop-log structures.- Concrete walls are proposed where space will not permit an earth section, namely, from a point just north of the Park River along the Connecticut River to high ground at the Memorial Bridge. The flood walls along the Connecticut

River will be 10 to 20 feet high and of the counterfort type with steel sheet pile cut-off. Stop-log structures are proposed at the present underpass beneath the New York, New Haven and Hartford Railroad. Concrete head walls are proposed at the two railroad crossings in the North Meadows to facilitate sandbagging during great floods. The concrete walls along the Park River will be counterforted retaining walls 20 to 40 feet above the river bed. The conduit under the wall along the Connecticut River will be of reinforced concrete with a head wall on the upstream side. The present bridges across the Park River will be replaced, with the exception of the Hudson Street bridge which will be provided with a new and higher deck.

i. Riprap protection.- Riprap is proposed along the earth dike in the vicinity of the Park River to within 5 feet of the top of the dike. The earth section north of the Memorial Bridge will be similarly protected from the bridge to the main line of the railroad in the North Meadow. The river bank will be graded and protected for about 2,500 feet above the Memorial Bridge and about 1,000 feet in the bight of the bend above the railroad bridge.

j. Drainage and pumping appurtenances.- A pumping plant with a capacity of 150 cubic feet per second is proposed in the North Meadows, where the present Meadow Brook crosses the dike line, to maintain the drainage of the area back of the dike during flood stages. An outlet structure will be constructed through the dike to take care of the drainage from the protected area during normal river stages. The gates in the outlet structure will be closed and the pumps started automatically when the Connecticut River is at flood stages and the surface water inside the dike is at 10 feet above mean sea level. Three pumping plants with intercepting sewers will be necessary in connection with the Park River protection. One plant with a capacity of 100 cubic feet per second will be located near the intersection of Ford and Asylum Streets to take care of a group of sewers entering into the Park River. A second plant with a capacity of 100 cubic feet per second will be located near the intersection of Wells and Hudson Streets to maintain the drainage of the intercepted sewers in this location. The third plant with a capacity of 100 cubic feet per second will be located near Front Street and will maintain the drainage of the remaining sewers entering Park River.

k. Estimated costs.- The following table gives the estimated costs of this plan of protection:

(Table on following page)

HARTFORD, CONNECTICUT

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Dike Construction				
	a. Along Connecticut River				
	Clearing		Lump Sum	$ 2,500	
	Concrete	12,900 cu.yds.	$15.00	193,500	
	Reinforcing steel	1,270,000 lbs.	0.05	63,500	
	Steel sheet pile	793,000 sq.ft.	1.00	793,000	
	Excavation and backfill	5,400 cu.yds.	1.00	5,400	
	Embankment, earth	174,000 cu.yds.	0.50	87,000	
	Embankment, earth	650,000 cu.yds.	0.25	162,500	
	Riprap	47,360 cu.yds.	5.00	236,800	
	Tile drain		Lump Sum	10,000	
	Gravel drain	40,000 cu.yds.	1.00	40,000	
				$1,594,200	
	Contingencies		20%	318,840	
				1,913,040	
	Engineering and overhead		15%	286,960	
	Total				$2,200,000
	b. Along Park River				
	Clearing		Lump Sum	10,000	
	Concrete	67,250 cu.yds.	13.00	874,250	
	Reinforcing steel	7,398,000 lbs.	0.05	369,900	
	Excavation and backfill	51,225 cu.yds.	2.00	102,450	
	Earth fill		Lump Sum	15,000	
	Conduit, concrete		Lump Sum	240,000	
	Reconstruction of bridges	4	Lump Sum	200,000	
				1,811,600	
	Contingencies		20%	362,320	
				2,173,920	
	Engineering and overhead		15%	326,080	
	Total				2,500,000
2.	Drainage and Pumping Facilities				
	Pumping plant	1-150 c.f.s.	Lump Sum	100,000	
	Pumping plant	3-100 c.f.s.	Lump Sum	210,000	
	Intercepting sewers		Lump Sum	70,450	
				380,450	
	Contingencies		20%	76,080	
				456,530	
	Engineering and overhead		15%	68,470	
	Total				525,000
3.	Rights of Way and Damages				
	Land		Lump Sum	50,000	
	Damages		Lump Sum	212,500	
				262,500	
	Legal, overhead and general expense		20%	52,500	
	Total				315,000
4.	Grand Total Capital Cost				$5,540,000
5.	Total Annual Cost				313,100

l. Value of protection.- The construction of the proposed protection will prevent the recurrence of the annual losses discussed in Paragraph 10 d. The estimated average annual benefit to the area protected is therefore $1,701,500.. This amount does not include a speculative benefit from the increase above the normal value of the land for its present use.

m. Plan of construction.- It is planned to complete the proposed work in two years. The City of Hartford is planning a boulevard and beautification system which will be incorporated with the flood protection works as much as possible. The plan of protection which will probably best suit these conditions is to construct the dike north of Memorial Bridge the first year. The concrete wall along the south side of the Park River, the concrete conduit to the Connecticut River and the earth section connecting the wall with the present Colt Dike enlargement will be constructed in the same year. The concrete wall along the north side of the Park River and the wall along the Connecticut River will be built the following year.

n. Effect of dike on flood heights and velocities.- Hydraulic studies indicate that the construction of the proposed dikes will have but a very slight effect on the flood heights and velocities in the river. Except in the North Meadows, the overbank section for which protection is proposed is largely built up and the area acts principally as a storage area rather than a floodway.

o. Attitude of local interests.- Local interests are planning a boulevard and beautification system in connection with flood control works. They have stated that it is their feeling that perhaps the flood protection should be built to the elevation of the maximum predicted flood. They also desire to have the United States build, in kind, a portion of their construction equal to the cost of the flood protection in locations that the flood control works can not be built to supplement their plans of construction, provided the plan adopted by the City is acceptable to the Engineer Department.

11. East Hartford, Connecticut.

a. Description of the Town.- The Town of East Hartford is situated on the east bank of the Connecticut River, 52 miles above the mouth and directly across from the City of Hartford. It covers an area of 18.2 square miles and had a population of 17,125 in the 1930 census. The principal business activities are the manufacture of aeroplanes and aeroplane engines, the distribution and sale of petroleum products, fertilizers, foddstuffs, automobiles, and building supplies.

b. Description of the flooded area.- The area subject to most frequent flooding is an alluvial plain about 3/4 of a mile wide having an elevation near the Connecticut River of about 20 feet above mean sea level and sloping gently downward to a swale at the foot of a bluff. A portion of the bluff was flooded for the first time during the flood of 1936. The development on the bluff consists of a few small industries, commercial establishments, and residences and apartment houses of well-built, medium-cost construction. The development on the low plain is principally low-cost residences, four marine ways, two sand and gravel companies, a bulk oil station, two boat clubs and an unloading wharf. Connecticut Boulevard, the prinicpal thoroughfare, leads to Memorial Bridge, crossing the middle of the inhabited low land on an earth fill and the swale on a masonry arch bridge. This street is lined with stores, automobile salesrooms, and apartments which were flooded during the 1936 flood.

c. Existing dikes.- There are no existing flood protection works at East Hartford. Public No. 409, 74th Congress, approved August 30, 1935, however, authorized the construction of dikes, drainage gates, suitable pumping plants and other facilities for controlling floods provided, that the cost of such work shall not exceed $658,000, and that the prosecution of this project shall be subject to approval by the Board of Engineers for Rivers and Harbors. In a report dated January 15, 1937, the District Engineer recommended the modification of the project as the result of a survey recommended by the Board of Engineers for Rivers and Harbors. The modified project recommended is identical with the plan included in this report.

d. Flood losses.- The amount of direct losses sustained during floods prior to 1936 is not available. Recent investigations show the direct losses caused by the 1936 flood to have been $1,324,000, of which $750,000 was urban, $511,500 industrial, $47,000 highway, and $15,500 railway. From the frequency-damage relationship, an annual direct loss of $46,000 was obtained for the area within the proposed dikes. It has been estimated that the indirect losses attributable to the flood such as loss of business, loss of employment, and interruption of transportation and communication with their consequent interference with regular activities are slightly higher than the direct losses. There has also been a marked decrease in the value of flooded property not reflected in the computation of the direct and indirect losses. From field investigation it is conservatively estimated that the property flooded in 1936 has suffered a decrease in capital value of 25 per cent as the result of the flood. The recoverable capital loss is 80 per cent of the total capital loss of $2,109,000, and amounts to $1,687,200. Based on a conservative yield of 6.0 per cent the average annual loss because of the reduction from normal values is $101,300. The average annual losses which are prevented by the proposed plan of dike protection are summarized in the following table, the direct and indirect losses having been reduced by the amount preventable by the Comprehensive Plan of reservoirs.

Annual Direct Loss	$9,000	
Annual Indirect Loss	$10,000	
Annual Loss from Decrease in Property Values	$101,300	
Total Annual Loss		$120,300

PLAN OF PROTECTION

e. Alignment.- The northern terminus of the proposed dike is the embankment of the New York, New Haven and Hartford Railroad at Prospect Street, which is above grade and serves as a dike for approximately 1,400 feet east of this point. From the point where the railroad leaves the bluff an earth dike is proposed along the north side of the railroad embankment for a distance of 2,900 feet to the bank of the Connecticut River, thence across the railroad tracks and 2,800 feet southerly along the bank of the Connecticut River to high ground at Connecticut Boulevard. The dike begins again just south of Connecticut Boulevard and runs 3,400 feet along the bank of the River, thence 3,000 feet east to the bluff along the Hockanum River, and thence along the top of the Bluff across Main Street terminating at high ground near Central Avenue. The alignment is indicated on Plate Number 145.

f. Subsurface investigation.- Subsurface samples taken with augers and core drills as shown on Plate Number 146 indicate that there is a 15 to 20 foot layer of relatively impervious silty sand material which overlays a more pervious stratum of water bearing sand. Preliminary permeability tests made on samples of the overlaying stratum indicate that seepage under the dike will not be sufficient to require a steel sheet pile cut-off wall except for a short section of the south dike at the swale where a portion of the cover stratum has eroded away.

g. Embankment.- The earth embankment will be subjected in maximum floods to heads of 15 to 25 feet in the low area. The section is designed with a crown width of 10 feet and side slopes of 1 vertical on 2.5 horizontal riverside, and 1 on 2 landside. A gravel-filled trench with subsurface tile drain leading to the pumping plants is proposed under the landisde toe to lower the saturation line through the dike and to concentrate seepage from under the dike during great floods. The dikes on the bluff will be subjected to lower heads and will have a crown width of 10 feet and 1 on 2 side slopes and will not have a gravel trench. The material will be well compacted silty sand obtained from the North and South Meadows outside of the protected area.

h. Concrete walls and stop-log structures.- The restricted space in the vicinity of the Shell Eastern Products Company necessitates a concrete wall approximately 400 feet long and 21 feet above ground. The wall will be of the counterfort type with steel sheet pile cut-off. Concrete stop-log structures, 25 to 30 feet high with 15-foot openings are proposed at the four marine ways and the unloading wharf. Concrete head walls for sandbagging are proposed at the New York, New Haven and Hartford Railroad tracks and at Main Street.

i. Riprap protection.- It is proposed to protect the earth dike along the Connecticut River where scour is anticipated with hand placed riprap to within 5 feet of the top of the dike. Riprap is also proposed along the north side of the dike in the vicinity of the railroad bridge, at all stop-log openings, and along the concrete wall at the Shell Eastern Products Company. In view of the anticipated increase in velocity caused by the flood protection, riprap of derrick size stone is proposed along the east bank above the railroad bridge, around the abutments and piers of the bridge, and along each bank for a short distance below the railroad and Memorial bridges.

j. Drainage and pumping appurtenances.- Two intercepting sewers are proposed to divert the storm and sanitary flow now controlled by lines located north and south of Connecticut Boulevard to two small pumping plants. The subsurface drains under the dike in this area will also run to the pumping plants. The present sewer outflows will be provided with gates to prevent flood waters from entering the system. The remaining storm sewers and subsurface drains that have natural drainage towards the swale area will discharge into the swale area, the lower portion of which is to be used as a storage basin during flood stages. A pumping plant with a capacity of 135 cubic feet per second is proposed at the lower end of the swale to provide drainage during flood stages. An intercepting sewer is proposed to divert the sanitary sewage from the bluff area through the pumping plant during very high floods.

k. Estimated costs.- The table on the following page gives the estimated costs of this plan of protection:

(Table on following page)

EAST HARTFORD, CONNECTICUT

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Dike Construction				
	Clearing		Lump Sum	$ 1,500	
	Concrete	7,100 yds.	$18.00	127,800	
	Reinforcing steel	780,000 lbs.	0.05	39,000	
	Steel sheet piling	32,000 sq.ft.	1.25	40,000	
	Excavation and backfill	8,000 cu.yds.	1.00	8,000	
	Embankment, earth	262,000 cu.yds.	0.25	65,500	
	Embankment, earth	306,000 cu.yds.	0.50	153,000	
	Riprap (one-man stone)	11,240 cu.yds.	5.00	56,200	
	Riprap (derrick stone)	7,500 cu.yds.	8.00	60,000	
	Gravel drain	39,000 cu.yds.	1.00	39,000	
	Tile drains		Lump Sum	20,000	
	Outlet structure		Lump Sum	2,500	
				612,500	
	Contingencies		20%	122,500	
				735,000	
	Engineering and overhead		15%	110,500	
	Total				$ 845,500
2.	Drainage and Pumping Facilities				
	Pumping plant	1-135 c.f.s.	Lump Sum	101,700	
	Pumping plant	2- 25 c.f.s.	Lump Sum	60,200	
	Intercepting sewer (30")	700 lin.ft.	4.50	3,150	
	Intercepting sewer (18")	700 lin.ft.	3.50	2,450	
	Intercepting sewer (15")	400 lin.ft.	3.00	1,200	
	Drainage gates	5	Lump Sum	140	
				168,840	
	Contingencies		20%	33,770	
				202,610	
	Engineering and overhead		15%	30,390	
	Total				233,000
3.	Rights of Way and Damages				
	Land			39,500	
	Damages			129,500	
				169,000	
	Legal overhead and general expense		20%	33,500	
	Total				202,500
4.	Grand Total Capital Cost				$1,281,000
5.	Total Annual Cost *				30,700

*Includes additional annual cost of Hartford dikes to provide for increased flood elevation, and increase in average annual damages above Hartford.

l. Value of protection.- The construction of the proposed protection will prevent the recurrence of the losses discussed in Paragraph 11 d. The estimated average annual benefit is therefore $120,300. This amount does not include a speculative increase above the normal value of the land for its present use.

m. Plan of construction.- It is planned to complete the construction in one year, the derrick-size riprap, and drainage and pumping appurtenances being commenced first. The concrete structures will be completed in advance of the earth fill.

n. Effect of dike on flood heights and velocities.- The closing of the swale which forms a channel during great floods will increase the flood heights and velocities in the main channel as indicated in the following table:

(Table on following page)

EAST HARTFORD, CONNECTICUT

EFFECT OF DIKES ON FLOOD STAGES AND VELOCITIES

Condition	Stage at Memorial Bridge (Feet)	Conn. River Channel Discharge (C.F.S.)	Railroad Bridge	Memorial Bridge	Section P	Section Q	Section R
			March 1936 Flood				
			Average Channel Velocities — Feet per Second				
Natural	37.3	189,000	4.4	5.4	5.3	4.2	4.3
Dikes plus Reservoirs Comprehensive Plan	33.2	226,000	5.6	7.0	7.1	5.8	5.9
			Maximum Predicted Flood				
Natural	40.2	209,000	4.4	5.7	5.3	4.3	4.4
Dikes plus Reservoirs Comprehensive Plan	35.0	248,000	6.1	7.4	7.4	6.0	6.2

The velocity at the Memorial Bridge, which is the critical section, will be 7.4 feet per second during the maximum predicted flood. Riprap will be provided at critical points to protect against scour caused by the increase in velocity. The increase in flood heights which will amount to about 1 foot at the railroad bridge has been considered in the design of the dike. The increase in the cost of the Hartford protection and the additional backwater damages caused by the proposed construction have been included in the annual charges for the protection, as it will close the swale area for flood flow and will not isolate the low area during great floods. The Chairman of the Town Council has stated by letter that the Town desires the United States to bear the entire cost of the dike construction, pumping and drainage facilities and rights of way as provided by the special legislation; but if this procedure is impossible, the Town is desirous of flood control to the extent, that in his opinion, it will pay something toward the project.

12. Springfield, Massachusetts.

a. Description of the City.- The City of Springfield is located on the east bank of the Connecticut River, about 76 miles above the mouth. The population, according to the 1930 census, was 149,900, and the incorporated area is 31.7 square miles. It is an important center of industry and commerce. Three main-line railroads, the Boston and Albany, Boston and Maine, and the New York, New Haven and Hartford enter and serve the various industries. Some of the more important products are electrical machinery, textiles, hardware, sporting goods, and automobiles. The home offices of several large insurance companies are located here.

b. Description of flooded area.- The area subject to disastrous floods is, for the most part, the low flood plain adjacent to the river. A point of the high land upon which the greater part of the city is built extends to the river in the vicinity of the Memorial Bridge, dividing this low plain into two distinct sections. The upstream area contains about 588 acres and is utilized for commercial, recreational and railroad facilities and structures. The downstream area is the smaller but more highly developed. It contains important railroad and industrial developments in addition to numerous smaller commercial buildings and low-cost residences and tenements. A small part of the central business area of the City in this section was flooded during the March 1936 flood. The total area covered by the 1936 flood for which dike protection is proposed contains about 819 acres and is shown on Plate Number 147.

c. Existing dikes.- The north residential section of the town was protected from Connecticut River floods by an earth dike extending from high ground within the Chicopee City line to the North End Bridge. This dike was overtopped by the flood of 1927 and the city rebuilt the structure to withstand a flood of similar magnitude. The rebuilt structure proved inadequate to withstand the flood of 1936 and was again overtopped and in many places washed away. The dike was reconstructed to the former grade and cross section by the City of Springfield as a local work relief project. Work is now underway by the Engineer Department to raise the existing dike to the Comprehensive Plan design grade as a work relief project.

d. Flood losses.- Although numerous historic floods have occurred, the only reliable data on flood losses were those compiled after the 1936 flood. All available information gathered from State and local agencies was supplemented by field inspection and investigation by this office. The direct damages within the area proposed for dike protection because of the 1936 flood have been estimated to be $3,701,000, distributed as follows: urban $1,574,000, industrial $1,804,000, highway $313,000 and railroad $10,000. From the damage-frequency relationship the annual direct losses for the area protected by the proposed dikes amount to $62,100. The indirect losses attributable to the flood by loss of business, loss of employment, and interruption of transportation and communication with their consequent interference with regular activities have been determined to be slightly greater than the direct losses. Over and above the direct and indirect losses there has also been a marked decrease in the value of the flooded property from the general trend of property valuations prior to the 1936 flood. From field investigation it has been conservatively estimated that the property flooded in 1936 has suffered a decrease in capital value of approximately 25 per cent, attributable directly to the flood menace. The recoverable capital loss is approximately 80 per cent of the total capital loss of $18,833,000, and amounts to $15,066,400. Based on a conservative yield of 6.0 per cent the average annual loss because of the reduction from normal values is $905,000. The average annual losses which are preventable by the proposed plan of dike protection are summarized in the following table, the direct and indirect losses having been reduced by the amount preventable by the Comprehensive Plan of reservoirs:

Annual Direct Loss	$ 11,700	
Annual Indirect Loss	$ 12,600	
Annual Loss from Decrease in Property Values	$905,000	
Total Annual Loss		$929,300

PLAN OF PROTECTION

e. Alignment.- The dike protection proposed for the City of Springfield is shown on Plate Number 147. The selection of a site for the protective dikes was limited by prior occupation of the lands by the buildings and structures which require the protection. As a result of such occupation the dike alighment and type of structure varies in the different reaches of the same dike. Economical and practical considerations primarily governed the selection of types of structure and alignment. The proposed plan of protection is a continuation downstream of the work underway above the North End Bridge by the Engineer Department as a work relief project and consists of the construction of a dike, extending from the North End Bridge southward to the high ground north of the Boston and Albany Railroad bridge, and from a point opposite Bridge Street southward to the South End Bridge. The intervening land is above flood stage and requires no protective structure. The proposed protection consists of an earth dike, concrete wall or the raising of the railroad subgrade, the type used being that most economical for the particular locality. Mill River will be carried through a pressure conduit of sufficient area to handle the maximum predicted discharge of the stream.

f. <u>Subsurface investigations</u>.- Subsurface investigations were made by auger borings at frequent intervals along the proposed dike line. The results of these investigations are presented graphically in Plate Number 143. In general, the borings indicate that in the upstream section from the North End bridge to the Boston and Albany railroad bridge the underlying strata consists of silty sand. The downstream section has been subjected to railroad fill and varies with the thickness of the fill that has been required. The filled-in section is composed of cinders of various thickness underlain by silty sand.

g. <u>Embankment</u>.- The earth dike will have a crown width of 10 feet and side slopes of 1 vertical on 2 horizontal. The maximum static head to which the structure will be subjected is about 10 feet. The quality of the underlying strata where this type of construction will be used is considered to be such that excessive seepage or piping is improbable. The fill material will be hauled in and will consist of a relatively impervious sandy clay material which with selective placement will form an impervious structure. Earth fill and rock ballast are proposed under short sections of the railroad track where raising the track will provide the most economical protection.

h. <u>Concrete walls and structures</u>.- Concrete walls are proposed where lack of space or other considerations make the earth section undesirable. The walls will be of the gravity and cantilever types and will vary in height from 5 to 12 feet. Because of their location in sections of the proposed dike where subsurface conditions are unfavorable, a steel sheet pile cut-off wall is provided.

i. <u>Riprap protection</u>.- Riprap paving is proposed along the earth dike in the upstream section from the North End Bridge to the Boston and Albany Railroad bridge. Paving is also provided where scour is anticipated along the bank at the locations of concrete walls and along the raised portion of the railroad embankment which serves as a dike.

j. Drainage and pumping facilities.- An effective system of pumping plants to control the sanitary and storm sewage during flood periods is a very necessary part of the proposed flood protective works and is shown on Plate Number 147. These plants will be placed near the outflow of the sewers and will be kept at a minimum by the concentration points where the pumping plants will be located. A pumping plant with a capacity of 320 cubic feet per second and with an intercepting sewer from the Cypress Street sewer is proposed at Clinton Street. A plant with a capacity of 390 cubic feet per second will be built at Worthington Street and will provide drainage of the Worthington Street sewer. A plant with a capacity of 160 cubic feet per second will be constructed at Union Street with an intercepting sewer from Elm Street. A plant with a capacity of 250 cubic feet per second is proposed for the York Street sewer. A proposed plant of 45 cubic feet per second capacity will be located along the south bank of Mill River and west of Columbus Avenue. Drainage gates will be constructed at existing sewers to prevent floods backing through the sewers into the proposed protected areas.

k. Estimate of costs.- The table on the following page gives the estimated cost of the proposed plan of protection:

(Table on following page)

SPRINGFIELD, MASSACHUSETTS

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Dike Construction				
	Concrete	4,150 cu.yds.	$16.00	$ 66,400	
	Reinforcing steel	454,000 lbs.	0.05	22,700	
	Steel sheet pile	99,200 sq.ft.	1.00	99,200	
	Excavation and backfill	6,400 cu.yds.	1.00	6,400	
	Removing R.R. side track	4,100 lin.ft.	1.00	4,100	
	Relaying R.R. side track	4,100 lin.ft.	2.00	8,200	
	Embankment, earth	41,000 cu.yds.	0.60	24,600	
	Earth fill (under sidetrack)	2,500 cu.yds.	1.00	2,500	
	Riprap	6,620 cu.yds.	5.00	33,100	
	Rock fill	2,000 cu.yds.	2.50	5,000	
				272,200	
	Contingencies		20%	54,400	
				326,600	
	Engineering and overhead		15%	49,000	
	Total				$ 375,600
2.	Mill River Tunnel				
	Concrete	5,200 cu.yds.	22.00	114,400	
	Reinforcing steel	530,000 lbs.	0.05	26,500	
	Excavation and backfill	3,600 cu.yds.	1.50	5,400	
	Reconstruction Columbus Ave. bridge		Lump Sum	5,000	
	Removal Main St. bridge		Lump Sum	4,000	
				155,300	
	Contingencies		20%	31,100	
				186,400	
	Engineering and overhead		15%	28,000	
	Total				214,400
3.	Drainage and Pumping Facilities				
	Pumping Plants				
	Clinton St.	1-320 c.f.s.	Lump Sum	142,000	
	Worthington St.	1-390 c.f.s.	Lump Sum	220,000	
	Union St.	1-160 c.f.s.	Lump Sum	130,000	
	York St.	1-250 c.f.s.	Lump Sum	174,000	
	Columbus Ave.	1- 45 c.f.s.	Lump Sum	40,000	
	Intercepting sewers		Lump Sum	133,000	
				839,000	
	Contingencies		20%	167,800	
				1,006,800	
	Engineering and overhead		15%	151,200	
	Total				1,158,000
4.	Rights of Way and Damages				
	Land		Lump Sum	35,000	
	Damages		Lump Sum	20,000	
				55,000	
	Legal, overhead and general expense		20%	11,000	
	Total				66,000
5.	Grand Total Capital Cost				$1,814,000
6.	Total Annual Cost				132,000

l. <u>Value of protection</u>.- The value of flood benefits as a result of construction of the recommended dikes is estimated to be $929,300 per annum. This value was determined by adding the direct and indirect flood losses discussed in Paragraph 12 d to the recoverable annual losses owing to depreciation of property values. An additional benefit not included in this figure and which is more or less speculative is that of increased real estate values above the normal value because of positive protection against future floods.

m. <u>Plan of construction</u>.- The plan of construction will require one year. It is proposed that the construction of the dikes, Mill River tunnel, and pumping plants be carried on concurrently.

n. <u>Effect of proposed works on flood heights and velocities</u>.- Because of the fact that the railroads and other structures in the low lands now occupy the great portion of the flood plain, the construction of dikes will not have material effect upon the floodway. The effect of the proposed protective works on the flood heights and velocities has been computed and has been found to be negligible.

o. <u>Attitude of local interests</u>.- The local authorities state by letter that they are in favor of the proposed plan, and that by the time construction plans are well underway the City of Springfield will be in a position to cooperate, as required by the Flood Control Act of 1936 and departmental policy requiring the localities benefited to furnish drainage and pumping facilities.

13. West Springfield, Massachusetts.

a. Description of the Town.- The Town of West Springfield is situated on the west bank of the Connecticut River, 76 miles above the mouth, and directly across from the City of Springfield. The town lies in the area along the Connecticut River north of and adjacent to the Westfield River at its confluence with the Connecticut River, and covers an area of 16.8 square miles. The population, according to the 1930 census, was 16,684. Located in the area adjacent to the Westfield River is the Eastern States Exposition grounds, the Boston and Albany Railroad shops, and a number of industrial concerns engaged in the manufacture of fibre boxes, glazed paper, pumps and pumping equipment, package machinery, foundry and machine-shop products, oil heaters, and petroleum products.

b. Description of flooded area.- The area subject to Connecticut River floods is an alluvial plain sloping gently away from the river towards the Westfield River. The section covered by the flood of March 1936 for which dike protection is proposed, as shown by Plate Number 149, is roughly rectangular in shape, about 1-1/4 miles wide by about 1-1/2 miles long with a frontage of about 2 miles along the Connecticut River, and covers about 1,044 acres. Practically all of the main residential district, industrial concerns, the Eastern States Exposition grounds, and the Boston and Albany Railroad shops are located in this flooded area.

c. Existing dikes.- An existing earth dike along the north bank of the Westfield River from the Connecticut River to the Agawam Bridge constructed by a group of private interests in 1917-1918, provides protection against frequent floods of the Connecticut River for the low area along the Westfield River to an elevation about three feet above the 1927 flood. A break in this dike caused most of the damage sustained in the 1927 flood, requiring subsequent repairs and strengthening.

A dike is under construction from about 3,000 feet north of the North End Bridge to the Memorial Bridge to the Comprehensive Plan design grade as a work relief project by the Engineer Department. This dike will provide partial protection to the low area in this section and is a link in the proposed plan of dike protection for the entire town.

d. Flood losses.- Records of flood damages sustained prior to March 1936 are not available. The direct losses caused by the 1936 flood within the area proposed for protection amount to $2,854,000. Of this total $1,483,000 is urban, $1,200,000 is industrial, $40,000 is highway, and $131,000 is railroad loss. From the damage-frequency relationship the annual direct losses for the area protected by the proposed dikes amount to $36,550. The indirect losses attributable to the flood such as loss of business, loss of employment, and interruption of transportation and communication with their consequent interference with regular activities have been determined to be slightly greater than the direct losses. Over and above the direct and indirect losses there has also been a marked decrease in the value of the flooded property from the general trend of property valuations prior to the 1936 flood. From field investigation it has been conservatively estimated that the property flooded in 1936 has suffered a decrease in capital value of approximately 25 per cent attributable directly to the flood menace. The recoverable capital loss is estimated at 80 per cent of the total capital loss of $4,000,000, and amounts to $3,200,000. Based on a conservative yield of 6.0 per cent the average annual loss because of the reduction from normal values is $192,000. The average annual losses which are prevented by the proposed plan of dike protection are summarized in the following table, the direct and indirect losses having been reduced by the Comprehensive Plan of reservoirs:

Annual Direct Loss	$ 5,350	
Annual Indirect Loss	$ 6,450	
Annual Loss from Decrease in Property Values	$192,000	
Total Annual Loss		$204,300

PLAN OF PROTECTION

e. Alignment.- The dike protection proposed for the Town of West Springfield is shown on Plate Number 149. The dike under construction by the Engineer Department as a work relief project provides protection from high ground about 3,000 feet north of the North End Bridge to the Memorial Bridge. The existing earth dike below the Memorial Bridge will be raised and enlarged, and extended along the Westfield River, above the Agawam Bridge, approximately 3,000 feet to high ground.

f. Subsurface investigations.- Investigations of subsurface conditions by auger borings, as shown on Plate Number 150, indicate a fairly deep overburden of a mixture of sand and silt along the Connecticut River, but variable sand and gravel along the Westfield River indicates the possibility of considerable seepage through the permeable stratum under the dike during periods of great flood.

g. Embankment.- The earth embankment will be subjected to varying heads up to a maximum of 20 feet near the mouth of the Westfield River in times of flood. The earth dike is designed with a crown width of 10 feet, a landside slope of 1 vertical on 2 horizontal, and a riverside slope of either 1 on 2 or 1 on 2-1/2 depending on height of proposed dike and condition of riverside slope of existing dike. The material used in the dike will be a well compacted mixture of sand and silt obtained from riverside borrow pits or from borrow areas north of the intersection of Park Street and South Boulevard.

h. Concrete walls and structures.- The existing concrete drainage conduit at the drainage gate located about 2,000 feet east of the Eastern States Exposition grounds will be lengthened to provide for the raising and enlargement of the earth dike.

i. Riprap protection.- The river bank between the North End Bridge and the Memorial Bridge will be provided with riprap protection where necessary to prevent scour and undermining of the dike. Other sections along the river bank and earth dike will be protected by riprap where scour is anticipated.

j. Drainage and pumping facilities.- A small pumping plant with capacity of about 15 cubic feet per second is proposed above the North End Bridge at the end of Warren Street to augment the existing system of pumping stations for maintaining drainage of the protected area during periods when river floods prevent drainage by gravity. Drainage gates will be installed on the Southworth Street and Warren Street sewers, and an intercepting sewer will be constructed to combine the flow of the two sewers during flood periods. Considerable storage area is available along the Westfield River east of the Eastern States Exposition grounds to impound storm water and seepage for short periods during flood stages.

k. Estimated costs.- The following table gives the estimated cost of the proposed plan of protection:

(Table on following page)

WEST SPRINGFIELD, MASSACHUSETTS

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Dike Construction				
	Clearing	[illegible] acres	Lump Sum	$ 5,000	
	Embankment, earth	250,000 cu.yds.	0.50	125,000	
	Rock fill	1,000 cu.yds.	2.50	2,500	
	Riprap	5,500 cu.yds.	5.00	27,500	
	Sewer outlet extension	1	Lump Sum	3,000	
				163,000	
	Contingencies		20%	32,600	
				195,600	
	Engineering and overhead		15%	29,400	
	Total				$225,000
2.	Drainage and Pumping Facilities				
	Pumping plant	1-15 c.f.s.	Lump Sum	15,000	
	Intercepting sewer (42")	600 lin.ft.	8.00	4,800	
	Drainage gates	2	Lump Sum	1,900	
				21,700	
	Contingencies		20%	4,400	
				26,100	
	Engineering and overhead		15%	3,900	
	Total				30,000
3.	Rights of Way and Damages				
	Land		Lump Sum	7,200	
	Damages		Lump Sum	2,000	
				9,200	
	Legal, overhead and general expense		20%	1,800	
	Total				11,000
4.	Grand Total Capital Cost				$266,000
5.	Total Annual Cost				$14,900

l. <u>Value of protection</u>.- The construction of the proposed protection will prevent the recurrence of the annual losses discussed in Paragraph 13d. The average annual benefit on account of flood prevention value of the dikes therefore is $204,300. This amount does not include a speculative increase above the normal value of the land for its present use.

m. <u>Plan of construction</u>.- It is planned to complete the project in one construction season.

n. <u>Effect of dike on flood heights and velocities</u>.- The overbank area along the Connecticut River is a small percentage of the total floodway area to the river, and as it is highly developed provides a high resistance to flow. The increases in flood heights and velocities in the Connecticut River that will result from the construction of the proposed dikes have been computed and are considered negligible.

o. <u>Attitude of local interests</u>.- The Chairman of the Board of Selectmen has stated by letter that the proposed plan of protection meets with the general approval of the Board, and that the Town of West Springfield will provide drainage and pumping facilities and comply with the requirements of the Flood Control Act of 1936.

14. Chicopee, Massachusetts.

a. Description of the City.- The City of Chicopee is located on the east bank of the Connecticut River, 80 miles above its mouth. The city is divided into two parts by the Chicopee River in its course to the Connecticut River, and has a total area of 22.9 square miles. According to the 1930 census the population was 43,930. The main industry is manufacturing, the principal products being radio apparatus, electrical machinery, apparatus and supplies, sporting and athletic goods, firearms, rubber tires and tubes, plumbing goods, foundry and machine-shop products, drop forgings, textile machinery and supplies, malt liquors, and meat packing.

b. Description of the flooded area.- The area subject to floods is the roughly convex-shaped flood plain extending from a point just north of the railroad and highway bridges leading to Holyoke, southward to the high land just south of the Chicopee River. The maximum width is about 4,000 feet and the length along the convex line formed by the Connecticut River about 16,000 feet. As indicated in Plate Number 151, certain irregular areas in the upper half of the plain are above the height of the 1936 flood but would be inundated by higher floods. The total flood area north of Chicopee River is approximately 1,000 acres, and south of the river is 20 acres. North of the Chicopee River the development consists of low and medium cost residences, small industrial concerns and numerous vegetable garden plots. To the south of the Chicopee River, and in its valley, are several large industrial concerns.

c. Existing dikes.- An earth dike was constructed along the Chicopee River and the Connecticut River in 1936 by the city, with Federal funds, as a work relief project. The dike was built to the approximate grade of the 1927 flood and provides protection to that stage for the lower half of the plain north of the Chicopee River.

d. Flood losses.- The amount of damages caused by floods prior to 1936 is not available. The direct losses sustained in the flood of March 1936 within the area protected by the proposed dikes amounted to $871,000, of which $334,000 is urban, $413,000 is industrial, $99,000 is highway and $25,000 is railroad loss. From the damage-frequency relationship the annual direct losses for the area protected by proposed dikes were found to be $13,590. The indirect losses attributable to the flood by the loss of business, loss of employment, and interruption of transportation and communication with their consequent interference with regular business activities have been determined to be slightly more than the direct losses. Over and above the direct and indirect losses there has also been a marked decrease in the value of the flooded property from the general trend of property values prior to the 1936 flood. From field investigation, it has been conservatively estimated that the property flooded in 1936 has suffered a decrease in capital value of approximately 25 per cent attributable directly to flood menace. The recoverable capital loss is approximately 80 per cent of the total capital loss of $1,480,000, and amounts to $1,184,000. Based on a conservative yield of 6.0 per cent this reduction from normal values amounts to an average annual loss of $71,200. The average annual losses which are prevented by the proposed dike protection are summarized in the following table, the direct and indirect losses having been reduced by the amount preventable by the Comprehensive Plan of reservoirs:

Annual Direct Loss	$ 2,280	
Annual Indirect Loss	$ 2,520	
Annual Loss from Decrease in Property Values	$71,200	
Total Annual Loss		$76,000

e. Alignment.- The dike plan proposed for flood protection of the City of Chicopee is shown by Plate Number 151. The dike will protect about 1,020 acres. The alignment begins in the Willimansett section, where a short earth dike and reinforced concrete flood wall along the east side of North Chicopee Street, with a stop-log structure at Prospect Street, will keep out flood waters due to headwaters of the brook or backwater from the Connecticut River above the bridges. A low ridge continues downstream along the river from the highway and railroad bridges to a meadow above Bonner Street and provides protection against floods to the Comprehensive Plan design grade except at three shallow swales across the ridge. Low dikes across the ends of these swales complete the chain of protection to Bonner Street. An earth dike runs from the ridge above Bonner Street to the river bank and thence downstream to the existing dike beginning at Liberty Street. This dike is raised and enlarged along the Connecticut River and up the Chicopee River to the Boston and Maine railroad embankment. A riverside slope fill continues along the railroad embankment, an opening about one foot below grade across the railroad tracks will be sandbagged during floods, and the existing dike to high ground at Bertha Avenue will be raised and enlarged to complete the dike alignment north of Chicopee River. For the area along the south bank of Chicopee River, a short earth dike from high ground at the lower dam and a combination of concrete walls and building wall reinforcement which connects with the upper side of the highway bridge at Springfield Street is proposed. Below the bridge a concrete wall continues along the river, between the top of the river bank and the roadway along the bank, to the Boston and Maine railroad embankment at the south end of the railroad bridge across the Chicopee River. The alignment on the opposite side of the railroad is resumed by a concrete wall along the top of the river bank for about 500 feet, and thence west and south with an earth dike along the top of the fill abutment to the spur track embankment. A stop-log gate structure across the spur track and a riverside slope fill on the spur track embankment brings the alignment back to the main line of the Boston and Maine railroad. On the east side of the railroad embankment a concrete wall along the lower side of the canal spillway tailrace to high ground near the canal spillway, with a stop-log gate structure at Depot Street, closes the chain of protection for the area along the south bank of the Chicopee River.

f. Subsurface investigations.- Explorations of subsurface conditions by auger borings, as shown on Plate Number 152, indicate an overburden composed of a mixture of sand and coarse silt for a depth of about 20 feet, and underlain with a stratum of variable sand and gravel for about 10 feet to the water table. These borings show the probability of a permeable stratum of sand or variable sand and gravel, but the thick overburden indicates that the danger of water boils during times of great flood is small. Rock outcrops along the south bank of the Chicopee River indicate a rock stratum under the alluvial overburden of silty sand.

g. Embankment.- The earth embankment will be subjected to heads varying from zero at the upper end in the Willimansett section to a maximum of 24 feet at the mouth of the Chicopee River. The dike section is designed with a crown width of 10 feet and riverside slope of 1 vertical on 2-1/2 horizontal and landside slope 1 vertical on 2 horizontal. The material used in the fill will be a mixture of silt, clay, and sand obtained from different points along the hill east of the railroad, and will be well compacted in the construction of the dike. A gravel filter drain will be provided under the landside toe of sections higher than 15 feet.

h. Concrete walls and structures.- Concrete walls are proposed where lack of space prevents the construction of earth dikes. The walls are of the cantilever type and do not exceed 7.5 feet above ground for the wall in the Willimansett section or 10 feet south of the Chicopee River. Steel sheet piling provided under the wall south of the Chicopee River will cut off seepage. Concrete stop-log structures are required for the opening at Prospect Street in the wall in the Willimansett section, and at Depot Street, and at the spur track south of Chicopee River. Retaining walls are provided at the opening that is to be sandbagged across the railroad tracks near Bertha Avenue.

i. Riprap protection.- Stone riprap is proposed on the river bank and the riverside slope of the dike along the two rivers where scour is anticipated.

j. Drainage and pumping facilities.- Pumping plants placed at points of natural drainage or at existing sewers along the dike alignment will provide drainage of the protected area during flood stages. A pumping plant with a capacity of 115 cubic feet per second is proposed in the Willimansett section near the Montgomery Street sewer, with intercepting sewers from Riverview Place and Leslie Street. A plant with a capacity of 125 cubic feet per second will be placed at the Call Street sewer, with an interceptor from the St. Louis Street sewer. A plant with a capacity of 180 cubic feet per second will provide drainage of the McKinstry Avenue sewer. A plant with a capacity of 70 cubic feet per second is proposed at the Paderewski Street sewer. Drainage of the open area east of the railroad and directly north of the Chicopee River will be provided by a plant, with capacity of 90 cubic feet per second, located at the dike near Bertha Avenue. For the industries south of Chicopee River three small plants, with capacities of from 5 to 25 cubic feet per second, will be placed in the three areas to provide drainage during flood. Drainage gates will be placed on existing outfalls to prevent floods backing into sewers under the dikes, and outlet structures at the pumping plants will minimize erosion due to the outfall from the pumps.

k. <u>Estimated costs</u>.- The following table gives the estimated cost of the proposed plan of dike protection:

(Table on following page)

CHICOPEE, MASSACHUSETTS

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Dike Construction				
	Clearing		Lump Sum	$ 5,000	
	Concrete	6,600 cu.yds	$16.00	105,600	
	Reinforcing steel	594,000 lbs.	0.05	29,700	
	Steel sheet piling	40,000 sq.ft.	1.25	50,000	
	Excavation and backfill	3,500 cu.yds.	1.00	3,500	
	Embankment, earth	302,000 cu.yds.	0.50	151,000	
	Riprap	23,200 cu. yds.	5.00	116,000	
	Gravel drain	14,000 cu.yds.	1.00	14,000	
	Tile drain		Lump Sum	10,000	
	Tailrace structures		Lump Sum	8,000	
				492,800	
	Contingencies		20%	98,600	
				591,400	
	Engineering and overhead		15%	88,600	
	Total				$680,000
2.	Drainage and Pumping Facilities				
	Pumping plant	1-180 c.f.s.	Lump Sum	103,000	
	Pumping plant	1-125 c.f.s.	Lump Sum	90,000	
	Pumping plant	1-115 c.f.s.	Lump Sum	75,000	
	Pumping plant	1- 90 c.f.s.	Lump Sum	60,000	
	Pumping plant	1- 70 c.f.s.	Lump Sum	50,000	
	Pumps	3- 10 c.f.s.	Lump Sum	16,000	
	Intercepting sewer (24")	2,375 lin. ft.	4.00	9,500	
	Intercepting sewer (36")	950 lin. ft.	6.00	5,700	
	Drainage gates	7	Lump Sum	8,600	
	Outlet structures	5	Lump Sum	4,500	
				412,300	
	Contingencies		20%	82,500	
				494,800	
	Engineering and overhead		15%	74,200	
	Total				569,000
3.	Rights of Way and Damages				
	Land		Lump Sum	30,800	
	Damages		Lump Sum	17,500	
				48,300	
	Legal, overhead and general expense		20%	9,700	
	Total				58,000
4.	Grand Total Capital Costs				$1,307,000
5.	Total Annual Cost				$84,900

l. Value of protection.- The construction of the proposed protection will prevent the recurrence of the annual losses discussed in Paragraph 14d. The average annual benefit from the flood prevention value of the dikes, therefore, is $76,000. This amount does not include a speculative increase above the normal value of the land for its present use.

m. Plan of construction.- It is planned to complete the project in one construction season. The concrete structures in and through the dike will be constructed in advance of the earth fill.

n. Effect of dike on flood heights and velocities.- The overbank area along the Connecticut River is only a small part of the total floodway area and the construction of dikes will eliminate only a very small percentage of the total flood flow. The effects of the proposed dikes on flood heights and velocities have been computed and are considered negligible.

o. Attitude of local interests.- Local authorities are in general agreement with the proposed plan of dike protection and with the provisions of the Flood Control Act of 1936, and feel that funds can be raised to provide drainage and pumping facilities as required by departmental policies.

15. Holyoke, Massachusetts.

a. Description of the City.- The City of Holyoke, located on the west bank of the Connecticut River 85 miles above the mouth, is a highly developed industrial city. It had a population of 56,537 (1930 census) and a total area of 20.9 square miles. A unique method of power distribution, by sale of water from a system of high-level canals, was, prior to the general use of hydro-electric power distribution, an important factor in the development of the town. The industries are for the most part engaged in the production of paper and paper products.

b. Description of flooded area.- The sections of the city which are subject to disastrous floods are the low areas adjacent to the river, now principally occupied by industrial plants and the railroads which serve them. High ground, directly above the Boston and Maine Railroad Bridge and on which is located one of the generating stations of the Holyoke Water Power Company, separates the two low areas. In the upper section this area is restricted by the prior construction of the high-level canals, while in the lower section the banks of the third level canal are not of sufficient height to prevent overtopping by a flood equal to that of 1936. In addition to the privately owned industrial plants, the city owns and operates a gas plant and a steam generating station in the upper section of the flooded area. There is also a small section of tenements in the lower flooded area. The area covered by the flood of March 1936 for which dike protection is proposed amounts to about 105 acres and is shown on Plate Number 153.

c. Existing dikes.- The high-level canals, although constructed for a quite different purpose, protect a considerable area that would otherwise be below maximum flood stages. After the flood of 1927 the Springdale Dike was constructed. This dike, an earth structure, was designed to protect the south area of the town against a recurrence of a flood equal in magnitude to that of 1927. This dike was overtopped in 1936 and a section of it destroyed. Reconstruction to the Comprehensive Plan design grade is now underway as a local work relief project by the City of Holyoke.

d. Flood losses.- Although numerous historic floods have occurred, the only reliable data on flood losses were those compiled after the flood of March 1936. The direct losses caused by the 1936 flood within the area proposed for protection amounted to $774,000. Of this total $35,000 is urban, $620,000 is industrial, $28,500 is highway, and $90,500 is railroad loss. From the damage-frequency relationship the annual direct losses for the proposed protected area amount to $8,330. The indirect losses attributable to the flood owing to loss of business, loss of employment, and interruption of transportation and communication with their consequent interference with the regular activities have been determined to be slightly greater than the direct losses. Over and above the direct and indirect losses there has also been a marked decrease in the value of the flooded property from the general trend of property valuations prior to the 1936 flood. It has been conservatively estimated from field investigation that the property flooded in 1936 has suffered a decrease in capital value of approximately 25 per cent attributable directly to the flood menace. The recoverable capital loss is approximately 80 per cent of the total capital loss of $2,940,000, and amounts to $2,352,000. Based on a conservative yield of 6.0 per cent the average annual loss, because of the reduction from normal values, is $141,000. The average annual losses which are preventable by the proposed plan of dike protection are summarized in the following table, the direct and indirect losses having been reduced by the amount preventable by the Comprehensive Plan of reservoirs:

Annual Direct Loss	$ 1,570	
Annual Indirect Loss	$ 1,670	
Annual Loss from Decrease in Property Values	$141,000	
Total Annual Loss		$144,240

PLAN OF PROTECTION

e. Alignment.- The dike protection for the City of Holyoke is shown on Plate Number 153. The site of the proposed work is limited by the presence of existing manufacturing plants and railroad tracks along the river bank to relatively narrow spaces either on the riverside or landside of the railroad. Lack of space makes necessary the use of concrete flood walls of the cantilever type throughout the greater portion of the work. From a point immediately below the Holyoke dam the proposed wall will extend downstream along the bank of the Connecticut River and along the upstream side of the No. 2 wasteway to the high ground near the overflow from the Second Level Canal. The wall then begins at the high bank of the Second Level Canal immediately below the overflow and extends along the downstream side of the No. 2 wasteway and along the bank of the Connecticut River, riverward of the railroad tracks, tying into high ground in the vicinity of Mosher Street with a short section of earth dike. A short section of earth dike beginning at the high ground near Appleton Street extends along the river bank landside of the railroad track to the White and Wycoff Building, which is to be reinforced to form a part of the protection. This building connects with the Boston and Maine Railroad embankment. A concrete wall begins at the downstream side of the railroad embankment and extends along the river bank on the landside of the railroad tracks to the No. 4 wasteway. The wall then extends along both sides of the No. 4 wasteway and along those parts on the banks of the Third Level Canal that are below the proposed grade. Below the No. 4 wasteway the wall extends along the river bank of the landside of the railroad track for a short distance, then along the riverside of the railroad track, tying into the existing Springdale dike with a short section of earth dike. The cost of the walls along the No. 4 wasteway and the low sections of the Third Level Canal is approximately equal to the cost of providing a suitable structure and control gates for closing the wasteway during flood stages. Features giving preference to the additional length of wall include: the saving incurred through the elimination of a pumping plant sufficient to provide drainage of leakage through the canal headgates and for storm water drainage into the entire canal system; the additional safety provided against a possible failure of either the headgates or the dam structures within the canal system, by maintaining a constant back pressure against these structures in allowing free flow of water through the canals at all times. The numerous tailrace tunnels will be provided with gates to prevent backwater from the Connecticut River entering the protected area during flood stages. These gates will be integral parts of the dike construction.

f. Subsurface investigations.- Numerous test holes were made along the proposed line of the dike to determine the subsurface condition of the underlying strata. The result of these investigations and other data on record are shown on Plate Number 154. In general, it was found that the upper surface had been filled with various materials, for the most part cinders and broken brick and stone, and this was inlaid by a strata of sand or sand mixed with gravel. Underlying this, at a greater depth, a few holes indicate a clay stratum such as usually precedes the bed or ledge rock. In general, the character of the investigation lead to the opinion that the entire dike be constructed with a steel sheet pile cut-off for the prevention of excessive seepage and serious piping.

g. Embankment.- Where used, the earth dikes will be less than 10 feet in height and will have a crown width of 10 feet and side slopes of 1 vertical on 2 horizontal. The fill will be secured locally and will consist of a well compacted sandy clay material well suited for this type of structure.

h. Concrete walls and structures.- The concrete walls, which are proposed to form the major part of the protective structure, will be of the reinforced concrete cantilever type of varying heights from 6 feet to 16 feet. Stop-log structures will be constructed integral with the dike and will be provided at all existing passages.

i. Riprap protection.- A study of the existing river currents indicates that the dike proper will not be subjected to general scour action; however, riprap is proposed along certain portions of the bank and dike where local scour is anticipated.

j. Drainage and pumping facilities.- Due to the utilization of water from the high-level canals, all the industries discharge large quantities of water through the dikes by means of tunnel tailraces. The flow of this water is regulated at the headgates in the canals; the outlets are uncontrolled. The flood water from the Connecticut River has free access to the tunnels under the existing conditions and the result would be an overflow of water into the industrial plants and a possible blow-up of the tunnels landward of the dikes. To prevent such occurrence, the tunnels will be provided with manually operated lift gates of steel construction fitted into concrete walls at the dike line. Leakage through these gates will be controlled by power pumps of adequate capacity. The greater portion of the storm and sanitary sewage will be deflected into pressure conduits or sewers and will require no additional control. Only the Jackson Street sewer will require a flood gate and pumping plant, the location of which is shown on Plate Number 153.

k. Estimated costs.- The table on the following page gives the estimated cost of the proposed plan of protection:

HOLYOKE, MASSACHUSETTS

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Dike Construction				
	Concrete	16,420 cu.yds.	$15.00	$ 246,300	
	Reinforcing steel	1,478,000 lbs.	0.05	73,900	
	Steel sheet piling	293,600 sq.ft.	1.00	293,600	
	Excavation and backfill	23,000 cu.yds.	1.00	23,000	
	Embankment, earth	13,000 cu.yds.	0.50	6,500	
	Riprap	1,200 cu.yds.	5.00	6,000	
	Reinforcing building to serve as dike		Lump Sum	5,000	
	Tailrace structures and gates		Lump Sum	180,000	
	Penstock structures and gates		Lump Sum	24,600	
	Removing railroad tracks	1,200 lin.ft.	1.00	1,200	
	Relaying railroad tracks	1,000 lin.ft.	2.00	2,000	
	Control gates No. 2 raceway		Lump Sum	10,000	
				872,100	
	Contingencies		20%	174,420	
				1,046,520	
	Engineering and overhead		15%	156,980	
	Total				$1,203,500
2.	Drainage and Pumping Facilities				
	Pumping plant	1-60 c.f.s.	Lump Sum	71,000	
	Pumps	15-5 c.f.s.(Average)	Lump Sum	32,000	
	Sewer diversion (20")		" "	13,000	
				116,000	
	Contingencies		20%	23,200	
				139,200	
	Engineering and overhead		15%	20,800	
	Total				160,000
3.	Rights of Way and Damages				
	Land		Lump Sum	61,820	
	Damages		Lump Sum	41,100	
				102,920	
	Legal, overhead and general expense		20%	20,580	
	Total				123,500
4.	Grand Total Capital Costs				$1,487,000
5.	Total Annual Costs				$86,500

l. Value of protection.- The value of flood benefits as a result of construction of the recommended dikes is estimated to be $144,240 per annum. This value was determined by adding the direct and indirect annual losses discussed in Paragraph 15 d to the annual recoverable loss because of depreciation of property values. An additional benefit not included in this figure and which is more or less speculative is that of increased real estate values above the normal value increase by positive protection against future floods. It is obvious that the lands subjected to frequent flooding are not desirable for further development but by removing the possibility of such damage, the potential value of the lands and existing structures will increase.

m. Plan of construction.- The project is planned for two construction seasons, the downstream section extending from the high ground, about 1,100 feet above the Boston and Maine Railroad bridge, south to the Springdale Dike being proposed for the first unit. The second unit from the Holyoke Water Power Company dam downstream to high ground, about 2,700 feet below the South Hadley Falls Bridge, will be constructed in the second year.

n. Effect of proposed works on flood heights and velocities.- Because of the narrow flood plain, which at present is at a relatively high elevation, and the numerous obstructions in this flood plain, the introduction of dikes will not materially affect either the height or the velocity of the flood waters. The effects of the dike on flood heights and velocities have been computed and are found to be negligible.

o. Attitude of local interests.- The City of Holyoke has stated by letter that the proposed plan of dike protection meets with the general approval of local interests, and that the interests and officials concerned have voted that the City of Holyoke should comply with the Flood Control Act of 1936 and with the governmental policy requiring local interests benefited to furnish adequate drainage and pumping facilities.

16. Northampton, Massachusetts.

a. Description of the City.- The City of Northampton is located along the west bank of the Connecticut River, 94 miles above the mouth. The major portion of the city is on high ground; Mill River running in a southeast direction to the Connecticut River divides the city into two parts. The total population indicated by the 1930 census was 24,381 and the total area is 34.6 square miles. A notable college for young women, other educational institutions, a large sanitarium, two large hospitals, and a few industrial concerns engaged in the manufacture of brushes, knit goods, and cutlery are located in the city.

b. Description of flooded area.- The area subject to frequent flooding is the agricultural lands on either side of the Mill River, downstream from the city proper. Mill River flows through this area southward to its confluence with the Connecticut River. The flood waters during the 1936 flood backed up the Mill River Valley and inundated portions of the main business district and a portion of the residential section in the city proper. Protective works are proposed for about 66 acres south and 109 acres north of the Mill River. In this area is located most of the manufacturing concerns and the municipal gas plant.

c. Existing dikes.- An earth dike was constructed in 1856-57 and enlarged in 1869 by a private dike company to afford flood protection to the developed area south of Mill River. This dike withstood the 1927 flood, but was overtopped by the flood of March 1936 by about 5 feet.

d. Flood losses.- The flood losses sustained in floods prior to March 1936 are not available. The direct losses resulting from the 1936 flood within the area proposed for protection by dikes amount to $438,000, of which $237,000 is urban, $176,000 is industrial and $25,000 is highway loss. From the damage-frequency relationship the annual direct losses for the area proposed for dike protection amount to $17,550. The indirect losses attributable to the loss of business, loss of employment, and interruption of transportation and communication, with their consequent interference with regular activities, have been determined to be slightly greater than the direct losses. Over and above the direct and indirect losses there has been a marked decrease in the value of the flooded property from the general trend of property values prior to the 1936 flood. Conservative estimates from field investigation show that the property flooded in 1936 has suffered a decrease in capital value of about 15 per cent, attributable directly to the flood menace. The recoverable capital loss is approximately 80 per cent of the total capital loss of $432,000, and amounts to $345,600. Based on a conservative yield of 6.0 per cent, the average annual losses because of the reduction from normal values amount to $20,700. The total average annual losses which are preventable by the proposed plan of dike protection are summarized in the following table, the direct and indirect losses having been reduced by the amount preventable by the Comprehensive Plan of reservoirs:

Annual Direct Loss	$2,690
Annual Indirect Loss	2,970
Annual Loss from Decrease in Property Values	20,700
Total Annual Loss	$26,360

e. Alignment.- (1) The dike protection proposed for the City of Northampton is shown on Plate No. 155. The dike will be constructed to the Comprehensive Plan design grade and will protect a total area of about 175 acres. The dike alignment begins with an earth dike at high ground near the south end of Pomeroy Terrace, proceeds southeast across Meadow Street, and thence southwest to Hockanum Road. A concrete cantilever wall continues upstream along Mill River at the riverside edge of Hockanum Road, passes under the Boston and Maine Railroad bridge, and continues along the river bank to the earth fill approach to the north end of the Wright Avenue highway bridge. An earth dike continues along the river bank to the New York, New Haven and Hartford Railroad. This railroad embankment is above dike grade and provides protection to a point about 600 feet below the New South Street Bridge. In this remaining distance to the north approach of the bridge a side track will be raised and short earth dike constructed to complete the protection. On the south side of Mill River an earth dike begins at the south approach to the New South Street Bridge and extends to the existing earth dike. A short concrete wall on the upper end of the existing dike is used for raising the dike where lack of space prevents additional earth section. The alignment then continued with the raising and enlarging of the exisitng dike to the Boston and Maine Railroad embankment. This railroad fill serves as protection for about 300 feet, after which a riverside fill on the embankment extends to a point opposite the existing earth dike at the junction of Mount Tom Road and Dike Road. This existing dike will be raised and enlarged, and concrete headwalls will be provided at the opening at the State highway and the railroad tracks to facilitate sandbagging during great floods. The Wright Avenue highway bridge will be raised about 7 feet to increase the floodway area of Mill River and to eliminate the necessity for stop-log openings at either end of the bridge. An earth dike extends upstream along the east bank of Mill River from the New York, New Haven and Hartford Railroad embankment to high ground near Smith College.

(2) The alternate plan advocated by certain local interests consists of an earth dike beginning at Pomeroy Terrace and Hancock Street and following along the alignment shown for the proposed plan to Hockanum Road, then extending directly across Mill River to a point where the exisitng dike intersects with the Boston and Maine Railroad embankment, thence along the existing lower dike to high ground. Dikes and floodwalls along the Mill River as shown in the proposed plan, are not required except for the short section of earth dike immediately above the New York, New Haven and Hartford Railroad bridge across Mill River, and the short section of earth dike immediately below this bridge that would serve as a diversion dam for Mill River. The flow from Mill River would be diverted from its present course to the Ox-Bow by a diversion canal to be excavated along the low ground or swale at the location indicated on Plate No. 155. The present bed of the river between the two dike crossings would be filled using the material in the existing dike between New South Street and the Boston and Maine Railroad for this purpose. Existing sanitary and storm water sewers that discharge into the section of the stream bed to be filled would be extended to the lower dike crossing.

f. <u>Subsurface investigations</u>.- The high ground at Northampton is the outwash of glacial lake bed deposits, while the low land beyond the edge of the high ground is an alluvial plain deposited by the Connecticut River. Auger borings along the proposed dike alignment north of Mill River indicate a stratum of silt changing to fine sand from Pomeroy Terrace to Hockanum Road with a water table about 2 feet below the surface of the low swale points. Along the north and south banks of Mill River the earth is silt changing to a variable medium sand and gravel, and then to a silty sand and silty clay at the New South Street bridge. At the lower end of the protected area south of Mill River the sandy material along the railroad changes to a silty sand and silty clay at high ground at the west end of the existing dike. The borings shown on Plate No. 156 indicate small likelihood of piping during high floods, but the high water-table from Pomeroy Terrace to Hockanum Road indicates the advisability of a subsurface drain under the landside toe of the proposed dike to provide drainage of the seepage away from the dike, thereby maintaining a low saturation line and protecting the stability of the soil structure.

g. Embankment.- Earth dikes will be used in the dike construction except where lack of space makes it more economical to construct concrete walls. The earth embankment in general will be subjected to varying heads up to a maximum of 18 feet at Hockanum Road. The earth fill is designed with a crown width of 10 feet and side slopes of 1 vertical on 2-1/2 horizontal, except where special conditions make it necessary to use a slope of 1 vertical on 2 horizontal. The material for the proposed embankment is a well compacted mixture of sand and silt to be obtained from the borrow areas along the riverside toe of the dike from Pomeroy Terrace to Hockanum Road, and along the Mill River below the proposed dikes. A gravel subsurface drain is proposed under the landside toe for earth dikes subjected to high heads.

h. Concrete walls and structures.- The concrete walls are of the cantilever type with steel sheet pile cut-off wall, and vary in heights up to a maximum height of 15 feet above ground at the lower end along Hockanum Road. Retaining walls will be constructed on either side of the Boston and Maine Railroad where it is proposed to end the earth fill and leave an opening of 5-foot depth to facilitate sandbagging during great floods. The Wright Avenue highway bridge will be raised and the abutments strengthened.

i. Riprap protection.- Stone riprap will be placed on the bank of Mill River and on the earth dike where scour is anticipated.

j. Drainage and pumping facilities.- A pumping plant of a capacity of 100 cubic feet per second will be located at Valley Street and Hockanum Road, with an intercepting sewer from the sewer that discharges into Mill River directly above the Wright Avenue highway bridge. Siphon ejectors with a capacity of 10 cubic feet per second are proposed at the sewer that leads under the railroad embankment to provide drainage for the area south of Mill River. Drainage gates will be provided to prevent backwater through existing sewers.

k. Estimated costs.- The following table gives the estimated costs of the proposed plan of dike protection:

(Table on following page)

NORTHAMPTON, MASSACHUSETTS

COST ESTIMATE

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Dike Construction				
	Clearing		Lump Sum	$ 4,200	
	Concrete	3,200 cu.yds.	$17.00	54,400	
	Reinforcing steel	288,000 lbs.	0.05	14,400	
	Steel sheet piling	33,600 sq.ft.	1.25	42,000	
	Excavation and backfill	3,100 cu.yds.	1.00	3,100	
	Embankment, earth	75,000 cu.yds.	0.50	37,500	
	Embankment, earth	132,000 cu.yds.	0.25	33,000	
	Riprap	3,100 cu.yds.	5.00	15,500	
	Raising bridge		Lump Sum	5,000	
	Removing R.R. track	600 lin.ft.	1.00	600	
	Relaying R.R. track	600 lin.ft.	2.00	1,200	
	Tile drains		Lump Sum	7,500	
	Gravel drain	12,000 cu.yds.	1.00	12,000	
				230,400	
	Contingencies		20%	46,100	
				276,500	
	Engineering and overhead		15%	41,500	
	Total				$318,000
2.	Drainage & Pumping Facilities				
	Pumping plant	1-100 c.f.s.	Lump Sum	65,000	
	Siphon ejector	1- 12 c.f.s.	Lump Sum	1,400	
	Intercepting sewers (48")	700 lin.ft.	10.00	7,000	
	Drainage gates	3	Lump Sum	7,700	
	Outlet structure	1	Lump Sum	800	
				81,900	
	Contingencies		20%	16,400	
				98,300	
	Engineering and overhead		15%	14,700	
	Total				113,000
3.	Rights of Way and Damages				
	Land			26,000	
	Damages			6,500	
				32,500	
	Legal, overhead and general expense		20%	6,500	
	Total				39,000
4.	Grand Total Capital Cost				$470,000
5.	Total Annual Cost				$ 29,200

l. Value of protection.- The construction of the proposed dikes will prevent the recurrence of the annual losses discussed in paragraph 16d. The average annual benefit from the flood prevention value of the dikes, therefore, is $26,360. This amount does not include a speculative increase above the normal value of the land for its present use.

m. Plan of construction.- It is planned to complete the project in one construction season. The intercepting sewer and pumping plant outlet structure should be constructed simultaneously with the wall along Hockanum Road to save duplication of excavation and disruption of traffic.

n. Effect of dike on flood heights and velocities.- As the dike is situated in close proximity to high ground, the overbank floodway area of the Connecticut River is reduced but very little by the construction, and the effects on flood heights and velocities of the Connecticut River are negligible.

o. Attitude of local interests.- Local authorities are in general agreement that flood protection by dikes is desirable but state that funds are not available for required local participation at this time. Certain local interests favor the alternate plan for the diversion of Mill River, which has many advantages in addition to Flood Control that makes it a more attractive plan to the City. As this plan is more expensive both to the United States and to local interests, it is considered that the cost of basic plan of dike protection should represent the maximum expenditure by the United States under existing Flood Control policies.

(Table on following page.)

TABLE NO. 53

SUMMARY OF DETAILS OF DIKES

THE FOLLOWING TABLE LISTS THE VARIOUS LOCALITIES OF DIKES, THE APPROXIMATE LENGTH OF EACH DIKE, AND THE QUANTITIES OF CONCRETE, REINFORCING STEEL, STEEL SHEET PILING, EXCAVATION, EMBANKMENT AND RIPRAP CORRESPONDING TO THE TOTAL CONSTRUCTION COST FOR EACH DIKE.

LOCALITY OF DIKE	TYPE	NET HEIGHT OF DIKE (FEET)	LENGTH OF DIKE (FEET)	CONCRETE (CU.YDS.)	REINFORCING STEEL (POUNDS)	STEEL SHEET PILING (SQ.FT.)	EXCAVATION & BACKFILL (CU.YDS.)	EMBANKMENT EARTH (CU.YDS.)	RIPRAP (CU.YDS.)	TOTAL FEDERAL COSTS (DOLLARS)
HARTFORD, CONN.	CONCRETE WALL AND EARTH DIKE	15-30	21,000	80,150	8,668,000	793,000	56,625	824,000	47,360	$4,700,000
EAST HARTFORD, CONN.	EARTH DIKE AND CONCRETE WALL	15-30	15,000	7,100	780,000	32,000	8,000	568,000	18,740	845,500
SPRINGFIELD, MASS.	EARTH DIKE AND CONCRETE WALL	8-12	12,000	9,350	984,000	99,200	10,000	43,500	8,620	590,000
WEST SPRINGFIELD, MASS.	EARTH DIKE AND CONCRETE WALL	5-20	14,100	NONE	NONE	NONE	NONE	200,000	11,500	225,000
CHICOPEE, MASS.	EARTH DIKE AND CONCRETE WALL	8-12	24,000	6,600	594,000	40,000	3,500	302,000	23,200	680,000
HOLYOKE, MASS.	CONCRETE WALL AND EARTH DIKE	5-14	17,400	16,420	1,478,000	293,600	23,000	13,000	1,200	1,203,500
NORTHAMPTON, MASS.	EARTH DIKE AND CONCRETE WALL	10-20	11,600	3,200	288,000	33,600	3,100	207,000	3,100	318,000
TOTALS			115,100	122,820	12,792,000	1,291,400	104,225	2,157,500	113,720	$8,562,000

TABLE 54

GENERAL DIKE DATA

Locality	Type of Dike	Approx. Height of Dike (Feet)	Approx. Length of Dike (Feet)	Approx. Area Protected (Acres)	Character of Area Protected	Assessed Valuation of Area Protected	Total Direct Flood Losses in Area Protected (1936)	Cost to United States for Construction	Costs to Local Interests: Rights of Way and Damages	Costs to Local Interests: Pumping Plants and Drainage Appurtenances	Costs to Local Interests: Total	Total Cost	Ratio Total Cost to Assessed Valuation (Per Cent)	Ratio Total Cost to 1936 Direct Flood Loss (Per Cent)
Hartford	Concrete wall & earth fill	20	21,000	2,755	Railroad industrial commercial residential	$135,600,000	$7,330,000	$4,700,000	$315,000	$525,000	$840,000	$5,540,000	4.1	75.6
East Hartford	Earth fill & concrete wall	20	15,000	582	Railroad commercial residential	8,454,000	1,324,000	845,500	202,500	233,000	435,500	1,281,000	15.2	96.8
Spring-field	Earth fill & concrete wall	10	12,000	819	Railroad industrial commercial residential	75,329,000	3,701,000	590,000	66,000	1,158,000	1,224,000	1,814,000	2.4	49.0
West Spring-field	Earth fill & concrete wall	12	16,800	1,044	Industrial commercial residential	16,048,000	2,854,000	225,000	11,000	30,000	41,000	266,000	1.7	9.3
Chicopee	Earth fill & concrete wall	10	24,000	1,020	Industrial commercial residential	5,909,000	871,000	680,000	58,000	569,000	627,000	1,307,000	22.1	150.1
Holyoke	Concrete wall & earth fill	10	17,400	105	Industrial Residential	11,720,000	774,000	1,203,500	123,500	160,000	283,500	1,487,000	12.7	192.1
Northamp-ton	Earth fill & concrete wall	15	11,600	175	Small commercial residential	2,716,000	438,000	318,000	39,000	113,000	152,000	470,000	17.3	107.5
Total			117,800	6,500		$255,776,000	$17,292,000	$8,562,000	$815,000	$2,788,000	$3,603,000	$12,165,000	4.8	70.4

FLOOD CONTROL

CONNECTICUT RIVER VALLEY

REPORT OF SURVEY

AND

COMPREHENSIVE PLAN

DETAILS AND ESTIMATES OF

CHANNEL IMPROVEMENTS

SECTION 6 OF THE APPENDIX

(VOLUME 2)

SECTION 6

CHANNEL IMPROVEMENTS

1. Scope.- This section of the Appendix presents studies of channel improvements at four reaches of the Connecticut River:

Middletown Narrows below Hartford, Conn.,

Pecowsic Narrows below Springfield, Mass.,

Smith Ferry Narrows above Holyoke, Mass.,

Wells River Bar at Wells River, Vermont.

It also contains estimates of the cost of these improvements, their probable effects on flood levels upstream and in their vicinity, and the probable benefits resulting from such improvements. These plans are based on engineering and economic data secured for the flood of March 1936, upon recent surveys, and upon data collected for the Document 308 Report.

2. Method of determining flood controlling effect.- Typical computations upon which the flood reductions are based, are summarized in Tables 55 to 60, inclusive. These show channel velocity heads and backwater computations under existing and modified conditions, the flood reduction being taken as the difference between present and modified water surface elevations. For the Narrows near Middletown, Springfield, and Holyoke, rational evaluations were made of the natural head losses during the March 1936 and November 1927 flood crests, the profiles thus computed being in substantial agreement with observed high water marks. The computed profiles are shown on Plates Nos. 157 to 163A, inclusive. The loss of head because of friction is determined by the Manning formula which is:

$$Q = \left[1.486 \, AR^{2/3} \right] \frac{S^{1/2}}{n}$$

in which Q = discharge in cubic feet per second

A = area of cross section in square feet

R = mean hydrulic radius in feet

S = ratio of fall due to friction loss to length of reach.

n = coefficient of roughness.

The term, "conveyance", used in the tables is the bracketed part of the above formula. Assuming overbank "n" to be 2.5 x channel "n", a total conveyance was computed as the sum of the channel conveyance plus 0.4 x the overbank conveyance. Allowance was made for head losses from curvature by increasing either the coefficient of roughness or the friction loss, the percentage increase depending upon the degree of curvature. Nagler's formula was used to determine the loss of head caused by bridge piers. Losses from changes of velocity were evaluated as follows:

Location	Head loss from Contraction	Head loss from Expansion
Below Hartford	0.2 x increase in velocity head	0.4 x decrease in velocity head
Below Springfield	0.2 x " " " "	0.4 x " " " "
Above Holyoke	0.35 x " " " "	0.70 x " " " "

The higher coefficients used above Holyoke were necessitated by the fact that in that relatively turbulent reach the cross sections measured were too far apart to include all the changes in velocity. In the Hartford Narrows study the head loss caused by eddies at Bodkin Rock were taken as 0.8 x velocity head at that point. Using the above head losses it was found that known flood profiles could be reproduced by backwater computations using these values for the coefficient of roughness:

Location	Channel "n" for 1936 flood	Channel "n" for 1927 flood
Below Hartford	.028	.026
Below Springfield	.0289	.0245
Above Holyoke	.033	.033

Profiles modified by channel enlargements were obtained by computations similar to those shown in Tables 58 and 60.

3. Method of determining flood controlling benefits.- Direct flood losses in selected damage zones affected by the various channel improvement plans were related to frequency by the method described in Section 2 of the Appendix, and average annual direct flood losses determined accordingly. Similar relations of flood losses to frequency, as modified by channel improvements, were prepared and the modified average annual direct flood loss determined. The direct flood controlling benefits are obviously the differences between the natural and modified flood losses. This evaluation was made for each channel improvement plan on three premises:

(a) No other flood controlling plan.

(b) Prior construction of reservoirs of Comprehensive Plan.

(c) Prior construction of Comprehensive Plan, reservoirs and dikes.

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(Report continued on following page)

4. Description of reach.- The reach of river considered extends from Enfield Rapids, where the effect of any channel improvement below Hartford disappears, to Paper Rock, at the downstream end of the improvements under consideration, a total distance of 41 miles. Special attention was given to the 24 miles from Hartford to Paper Rock where the greatest flood losses in Connecticut have occurred. Through the Enfield Rapids for a distance of 5 miles the valley is narrow and the flood slope comparatively great, being about 3.6 feet per mile. In the following reach, about 26 miles in length, including Hartford and extending to Gildersleeve Island, the valley is more than a mile wide and the flood slope uniformly about 0.3 foot per mile. In the remaining eight miles to Paper Rock the valley gradually narrows, swings from its previous southerly direction towards the southwest and then gradually turns eastward until below Middletown it has taken an easterly direction. The average flood slope in this reach is 0.9 foot per mile, part of the fall being concentrated at the "Straits" between Bodkin Rock and Paper Rock. A general map of the river below Hartford is shown on Plate No. 157. In the absence of contours fifteen exaggerated cross-sections are shown on the map, so plotted that the March 1936 high water elevations coincide with the cross-section lines. The March 1936 and November 1927 high water profiles are shown on Plate No. 160.

5. Scope.- This study presents two plans, designated Plans A and B, for channel improvement below Hartford. Plan A provides for enlarging the constricted flood channel at Bodkin Rock and straightening the shore line on the left bank of the "Straits" about 2.2 miles below Middletown. Plan B provides for an auxiliary flood channel to be excavated across the bend from Gildersleeve Island through Job's Pond to a point about 300 feet below Paper Rock. The total length of

the channel is 4.0 miles while the corresponding distance by river around the bend is 7.6 miles. Estimates of costs, the reduction of flood heights, and the resultant benefits at Hartford, Middletown, and other areas affected are presented for both plans.

6. Problem.- From examination of the March 1936 high water profile it can be seen that two-thirds of the fall from Hartford to Paper Rock is concentrated in the bend and constrictions of the lower third of the reach, below Gildersleeve Island. Any reduction of the flood slope in this reach would lower flood stages at Hartford, Middletown and adjacent areas where the greatest flood losses in Connecticut have occurred. The topography lends itself to two possible methods of effecting such a reduction, the economic justification of either method depending upon the relative cost and value of the flood reduction secured.

7. Description of Plan A.- Plan A provides for enlarging the flood channel at Bodkin Rock and for straightening the shore line on the left bank as shown on Plate No. 158, the line of the cut to be so placed that the maximum reduction in flood velocity for the amount of material excavated would be obtained. Bodkin Rock is located on the left bank at the upstream entrance to the "Straits" approximately 29.2 miles above Saybrook Light and 2.2 miles below Middletown. The cross-sectional area of the channel at the 1936 flood crest is less than 40,000 square feet for a distance of 700 feet above the promontory and 1,300 feet below it, with a minimum area of 34,000 square feet. By Plan A a uniform cross-sectional area of 40,000 square feet would be obtained. It is estimated that this would require approximately 8,400 cubic yards of earth excavation and 394,300 cubic yards of rock excavation at a total cost of $832,200. The surface of practically the entire section is exposed ledge rock. The details of the estimate follow:

ESTIMATE OF COST - PLAN A

Item No.	Item	Quantity and Unit	Unit Cost	Amount	Total
1.	Construction				
	Preliminary investigation		Lump Sum	$ 3,000	
	Clearing	3 ac.	75.00	225	
	Excavation, earth	8,426 c.y.	.40	3,370	
	Excavation, rock, dry	344,250 c.y.	1.50	516,375	
	Excavation, rock, under-water	50,046 c.y.	4.00	200,184	
				723,154	
	Contingencies and overhead		15%	108,846	
	Total				$832,000
2.	Relocation of Railroads and Utilities				None
3.	Rights of Way and Land				
	Land	6 ac.	30.00	180	
	Contingencies and overhead		15%	20	
	Total				200
4.	Highway Relocation				None
5.	Grand Total Capital Cost				$ 832,200

The annual charge against this capital cost is about $38,760.

8. Flood controlling effect of Plan A.- In the reach of river directly above and below Bodkin Rock it is estimated that at the March 1936 flood crest the head loss by eddies was 0.87 foot; by channel friction, 1.09 feet; and by curvature, contraction and expansion, 0.24 foot. With the channel straightening and widening proposed in Plan A it is estimated that the head loss by eddies would have been eliminated; that the head loss by channel friction would have been reduced to 0.71 foot; and by curvature, contraction, and expansion, to 0.18 foot. The net result is that the March 1936 flood stage at the upper end of the proposed improvement would have been reduced 1.31 feet. This effect

would become less pronounced as it moved upstream and converged with the natural profile in the Enfield Rapids. In the following table are given natural and modified water surface elevations and stage reductions at several points for the 1927 and 1936 floods. On Plate No. 160 the 1936 modified profile is shown. Since the hydraulic computations necessary to evaluate head losses in a river at flood stage are somewhat arbitrary in their nature, the reductions by the proposed improvement were intentionally computed at their maximum reasonable values so that the resulting benefits would represent the maximum probable.

1936 AND 1927 FLOOD REDUCTIONS - PLAN A

Division	Location of Index Stage	1936 Flood			1927 Flood		
		Nat. Elev.	Mod. Elev.	Red. Ft.	Nat. Elev.	Mod. Elev.	Red. Ft.
Above Enfield Rapids	Thompsonville	58.99	58.99	0	53.00	53.00	0
Windsor Locks to Hartford	Windsor Locks	40.52	40.23	.29	35.00	34.79	.21
Hartford and E. Hartford	Hartford	37.14	36.71	.43	28.37	28.06	.31
Hartford to Cromwell	Wethersfield	35.75	35.25	.50	26.34	25.98	.36
Cromwell and Portland	Cromwell	31.36	30.15	1.21	22.04	21.17	.87
Middletown	Middletown	30.62	29.34	1.28	21.37	20.45	.92

9. Average annual benefits by Plan A.- The average annual reduction of direct loss, and its ratio to annual cost are shown in the following table for Plan A alone, Plan A after completion of the reservoirs of the Comprehensive Plan, and Plan A after completion of Comprehensive Plan, including reservoirs and dikes.

(Table on following page)

Damage Zone	Average Annual Reduction Plan A Alone	Plan A after Comprehensive Reservoir Plan	Plan A after Comprehensive Reservoir Plan and Dikes
Windsor Locks to Hartford	$ 450	$ 70	$ 70
Hartford and E. Hartford	23,400	4,560	0
Hartford to Cromwell	460	100	100
Cromwell and Portland	1,960	950	950
Middletown	3,880	1,320	1,320
	$30,150	$7,000	$2,440
Ratio Direct Benefit / Cost	0.77	0.132	0.063

Since total benefits are shown in Section 2 of the Appendix to be between 2 and 3 times the reduction of direct loss, Plan A can be justified economically if considered alone but not if reservoirs and dikes are constructed. Since the Comprehensive Reservoir Plan is justified Plan A cannot be justified.

10. Description of Plan B.- Plan B provides for an auxiliary flood water canal to be excavated from the Connecticut River at Gildersleeve Island across the bend through Job's Pond to a point about 300 feet below Paper Rock. The general plan, profile along the center line, and representative cross-sections of the canal are shown on Plate No. 158. The total length of the canal would be 4.0 miles, whereas the corresponding distance around the bend is 7.6 miles. The canal would have a uniform bottom width at mean sea level of 600 feet and side slopes of 1 on 2 in earth and of 4 on 1 in rock. The average depth of cut would be 68 feet and the maximum, 190 feet. The resultant total volume of excavation would be 38,400,000 cubic yards, of which 1,100,000 cubic yards are assumed to be rock, based on scattered rock outcroppings at the lower end of the canal, no borings having been made. The side of the canal would be riprapped to the maximum flood level. In order to prevent the ultimate formation by scour of an

auxiliary low water channel that would divide the low water flow and increase the formation of bars in both channels, a mass concrete spillway would be provided with a crest elevation of 4.0 feet above mean sea level, to be founded on rock if encountered within a feasible depth. An outcropping of rock in the vicinity of the proposed spillway location merely indicates suitable foundation conditions, as no borings have been made. It is estimated that the natural water surface elevation in the river is below the proposed spillway crest elevation 90 per cent of the time and that no increase in dredging costs to maintain the existing navigation channel around the bend would result from the diversion of flow through the canal when the river rises above the spillway crest. Its location is shown on the general plan of Plate No. 158. About 1,900 acres of land would be required of which about 500 acres are good tobacco land and the remainder consists of meadows, pastures, sparsely wooded hillsides, and swampy bottom. Eleven sets of farm buildings and 30 summer cabins in the vicinity of Job's Pond are within the area to be excavated. The canal site is traversed by 5 highways and minor crossroads. It is proposed to provide bridges for two of the highways. The air line division of the New York, New Haven and Hartford Railroad crosses the canal site on a fill at an elevation of 126.7 feet above mean sea level, necessitating a single track railroad bridge with a length of about 1,000 feet.

The estimated cost of Plan B is $13,992,000, the details of which are as follows:

(Table on following page)

ESTIMATE OF COST - PLAN B

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Preliminary investigation		Lump Sum $	20,000	
	Clearing	380 ac.	$40.00	15,200	
	Excavation, rock	1,005,170 c.y.	1.30	1,423,700	
	Excavation, earth	37,268,150 c.y.	.25	9,317,000	
	Spillway, concrete	12,720 c.y.	10.00	127,200	
	Riprap - stone	90,180 c.y.	3.00	270,500	
				11,173,600	
	Contingencies and overhead		15%	1,676,400	
	Total				$12,850,000
2.	Relocation and Railroads and Utilities				
	Railroad relocation	.3 mi.	100,000	30,000	
	Railroad bridge	1,040 ft. long	Lump Sum	365,800	
	Transmission line (1200 feet anchorage crossing)		" "	5,000	
	Minor telephone and transmission lines	5 mi.	2,800	14,000	
				412,800	
	Contingencies and overhead		15%	62,200	
	Total				475,000
3.	Rights of Way and Land				
	Land	1,900 ac.	Lump Sum	141,100	
	Buildings purchased	11 sets 30 summer cottages	" "	73,000	
				214,100	
	Contingencies and overhead		15%	32,900	
	Total				247,000
4.	Highway Relocation				
	18-foot Concrete	.6 mi.		28,500	
	18-foot Macadam	1.3 mi.		35,500	
	Bridges	2		301,400	
				365,400	
	Contingencies and overhead		15%	54,600	
	Total				420,000
5.	Grand Total Capital Cost				$13,992,000

The annual charge against this capital cost is about $713,892.

11. Flood controlling effect of Plan B.- The total head loss in the Connecticut River from Gildersleeve Island to Paper Rock during the March 1936 flood crest was 6.91 feet, and during the November 1927 flood crest, 6.14 feet. The auxiliary flood water canal proposed in Plan B would have diverted 35 per cent of the discharge from this reach of the main river during the 1936 flood crest, and as a result would have lowered the high water elevation at Gildersleeve Island 3.69 feet. It is estimated that the canal would have carried 27 per cent of the discharge during the 1927 flood crest and would have lowered the high water elevation at Gildersleeve Island 3.10 feet. This effect would have been less pronounced as it moved upstream and converged with the natural profile in the Enfield Rapids. In the following table are given natural and modified water surface elevations and stage reductions at several points for the 1927 and 1936 floods. On Plate No. 160 the 1936 modified profile is shown.

1936 AND 1927 FLOOD REDUCTIONS - PLAN B

DIVISION	Location of Index Stage	1936 Flood			1927 Flood		
		Nat. Elev.	Mod. Elev.	Red. Ft.	Nat. Elev.	Mod. Elev.	Red. Ft.
Above Enfield Rapids	Thompsonville	58.99	58.99	0	53.00	53.00	0
Windsor Locks to Hartford	Windsor Locks	40.52	38.72	1.80	35.00	33.49	1.51
Hartford and E. Hartford	Hartford	37.14	35.02	2.12	28.37	26.59	1.78
Hartford to Cromwell	Wethersfield	35.20	32.40	2.80	26.34	23.99	2.35
Cromwell and Portland	Cromwell	31.36	28.41	2.95	22.04	19.56	2.48
Middletown	Middletown	30.62	28.02	2.60	21.37	19.19	2.18

Investigation has also been made of the possibility of excavating only a pilot channel at the location of Plan B and of depending upon the flood flow of the river to scour the channel to a cross-sectional area sufficient to produce appreciable stage reductions. The principal merit of this method is its low initial cost. There are two major objections to it, the uncertainty of obtaining appreciable stage reductions, and the injury to the navigable channel below that would result. With regard to the former, it might take several disastrous floods to scour the pilot channel to appreciable size, and during these floods, the slight stage reduction would be of little value. Concerning the latter, it is probable that the formation of bars in the lower Connecticut River by silting after every flood would materially increase the cost of channel maintenance. In view of these probabilities it is considered that this method of reducing floods cannot be justified.

12. Average annual benefits by Plan B.- The average annual reduction of direct loss, and its ratio to annual cost are shown in the following table for Plan B alone, Plan B after completion of reservoirs of the Comprehensive Plan, and Plan B after completion of the Comprehensive Plan including reservoirs and dikes.

Damage Zone	Average Annual Reduction		
	Plan B Alone	Plan B after Comprehensive Reservoir Plan	Plan B after Comprehensive Reservoir Plan & Dikes
Windsor Locks to Hartford	$ 2,010	$ 310	$ 310
Hartford and E. Hartford	87,100	17,550	0
Hartford to Cromwell	2,180	400	400
Cromwell and Portland	4,400	1,240	1,240
Middletown	7,570	2,550	2,550
Totals	$103,260	$22,050	$4,500
Ratio Direct Benefit / Cost	0.145	0.031	0.006

Although total benefits may be 2 or 3 times the direct benefits, it can be seen that Plan B is not justified alone or in combination with any other flood control plan.

STUDY OF CHANNEL IMPROVEMENT BELOW SPRINGFIELD

13. Description of reach.- The reach of river studied extends from the foot of Holyoke Dam in Holyoke, Mass. where the effect of any channel improvement below Springfield disappears, to the lower end of the Pecowsic Narrows below Springfield. Special attention was given to the lower 4 miles below North End Bridge, Springfield, where the greatest flood losses have been suffered. The total length of the reach is about 13.0 miles, the river flowing in a generally southerly direction in a series of wide bends. From Holyoke to Chicopee, a distance of about 6.0 river miles, the river valley is over a mile in width and has a fairly uniform slope of about 0.92 foot per mile. The main river is joined by the Chicopee River just above the City of Chicopee, and from that point to the North End Bridge in Springfield the valley narrows somewhat, while the channel undergoes several gradual changes in section and direction. The distance covered in this part of the reach is about 3.0 miles with an average slope of about 0.30 foot per mile. In the remaining 4 miles the river flows in a southeasterly direction with a mean flood slope of 1.00 foot per mile through the City of Springfield past the mouth of the Westfield River, to Pecowsic Point, where it enters the constricted section known as the Narrows. The flood slope through the Narrows is about 1.66 feet per mile. A general plan of the river in the vicinity of Springfield is shown on Plate No. 161. Nine exaggerated cross-sections are shown on the plan, so plotted that the March 1936 high water elevations coincide with the cross-section lines. The high water profiles computed for the March 1936 and November 1927 floods are also shown on Plate No. 161. Simultaneous stage readings were taken at several points in this reach when the 1936 flood had receded to the November 1927 high water stage at Memorial Bridge, Springfield. The resulting profile showed a much flatter flood slope

at the Narrows than existed at the 1927 peak, indicating scour during the intervening period. Cross-sectional data obtained in 1903 and following the 1936 flood show considerable scour, a large part of which may have occurred during the 1936 flood. Since it is believed that a recurrence of the 1927 flood would produce a high water profile in substantial agreement with the simultaneous stage readings referred to above, the profile based on them has been used as the 1927 flood profile.

14. Problem.- Examination of the high water profiles for the March 1936 and November 1927 floods reveals a slight increase in the flood slope through the Narrows. Reduction of this flood slope would result in slightly lower flood levels at Springfield and Chicopee and points upstream as far as the foot of Holyoke Dam. The most logical method of effecting this reduction appears to be the removal of Pecowsic Point, thereby widening the flood channel and increasing its carrying capacity. The two plans studied, designated as Plans A and B, differed only in the extent of the enlargement provided.

15. Description of Plan A.- Plan A provides for enlargement of the flood channel at the Pecowsic Narrows by removal of Pecowsic Point and straightening the shore line on the left bank as shown on Plate No. 162. Pecowsic Point is located on the left bank of the river just below the mouth of Pecowsic Brook, and marks the upstream entrance to the Narrows. The cross-sectional area of the channel at the 1936 flood crest is less than 46,400 square feet for a distance of about 1,000 feet above Pecowsic Point and for about 3,000 feet below it, with a minimum area of 35,500 square feet at the most constricted section. The line of cut is so placed that the enlarged channel would have sufficient carrying capacity to pass a flood of the magnitude of the March 1936 flood without any change in the slope

of the velocity head profile throughout that section of the river. A minimum cross-sectional area of 46,400 square feet would thereby be obtained. It is estimated that this would require approximately 2,025,700 cubic yards of earth excavation and 239,100 cubic yards of rock excavation with a total cost, including rights of way, land, and relocations, of $1,233,900. Rock is assumed to extend back horizontally from its outcropping on the river bank, no borings having been made. The details of the estimate follow:

ESTIMATE OF COST - PLAN A

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Preliminary investigation		Lump Sum	$ 1,000	
	Clearing	30 ac.	" "	2,000	
	Excavation, earth	2,025,700 c.y.	0.25	506,425	
	Excavation, rock	239,100 c.y.	1.50	358,560	
	Concrete, reinforced	1,000 c.y.	15.00	15,000	
				882,985	
	Contingencies and overhead		15%	132,415	
	Total				$1,015,400
2.	Relocation of Railroads and Utilities				
	Railroad relocation	0.72 mi.	Lump Sum	30,000	
	Contingencies and overhead		15%	4,500	
	Total				34,500
3.	Rights of Way and Land				
	Land (City Park)	35 ac.	Lump Sum	140,000	
	Buildings purchased		" "	20,000	
				160,000	
	Contingencies and overhead		15%	24,000	
	Total				184,000
4.	Highway Relocation				None
5.	Grand Total Capital Cost				$1,233,900

The annual charge against this capital cost is about $57,500.

16. Flood controlling effect of Plan A.- In the reach of river included within the Narrows section, it is estimated that the head loss at the March 1936 crest from channel friction was 0.67 foot and loss from curvature, contraction, and expansion combined was 0.32 foot. As a result of the channel enlargement and straightening as proposed in Plan A, it is estimated that the loss from channel friction would have been reduced to 0.44 foot and the losses from contraction and expansion would have been practically eliminated. The curvature loss would have been reduced to 0.09 foot. The net result is that the March 1936 maximum flood level would have been reduced 0.46 foot at the Memorial Bridge and 0.25 foot at the Chicopee Highway Bridge. The reduction in flood levels becomes less pronounced as the computations proceed upstream until finally the natural and modified profiles coincide. The following table gives the natural and modified water surface elevations and stage reductions at both points for the 1936 and 1927 floods.

1936 AND 1927 FLOOD REDUCTIONS - PLAN A

Location of Index Stage	March 1936 Flood			November 1927 Flood		
	Nat. Elev.	Mod. Elev.	Red. Ft.	Nat. Elev.	Mod. Elev.	Red. Ft.
Memorial Bridge, Springfield	66.04	65.58	0.46	59.78	59.55	0.23
Chicopee Highway Bridge	69.45	69.20	0.25	62.39	62.27	0.12

17. Average annual benefits by Plan A.- The average annual reduction of direct loss, and its ratio to annual cost are shown in the following table for Plan A alone, Plan A after completion of the reservoirs of the Comprehensive Plan, and Plan A after completion of Comprehensive Plan including reservoirs and dikes.

(Table on following page)

Damage Zone	Plan A Alone	Plan A after Comprehensive Reservoir Plan	Plan A after Comprehensive Reservoir Plan and Dikes
Springfield Dike Area	$ 8,400	$2,240	$ 0
W. Springfield Dike Area	3,930	750	0
Remaining area affected by channel improvement	3,640	975	120
Totals	$15,970	$3,965	$120
Ratio $\frac{\text{Direct Benefit}}{\text{Cost}}$	0.278	0.070	0.002

Although total benefits may be 2 or 3 times the direct benefits, it can be seen that Plan A is not justified alone nor in combination with any other flood control plan.

13. Description of Plan B.- Plan B is an alternate plan for removal of Pecowsic Point similar in intent and purpose to Plan A, but much more limited in its scope and effect. The line of cut and amount of channel enlargement are based on field data and studies made by the Springfield City Planning Board. The plan of the cut, profiles and typical cross sections are shown on Plate No. 162. By Plan B the channel area at the most constricted section is increased from 35,500 square feet to 39,200 square feet. It is estimated that this cut would require approximately 294,300 cubic yards of earth excavation and 35,200 cubic yards of rock excavation at a total cost of $193,000 as itemized in the following table. Rock is assumed to extend back horizontally from its outcropping on the river bank, no borings having been made.

(Table on following page)

ESTIMATE OF COST - PLAN B

Item No.:	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Preliminary investigation		Lump Sum $	1,000	
	Clearing	5 ac.	" "	375	
	Excavation, earth	294,300 c.y.	$0.25	73,575	
	Excavation, rock	35,200 c.y.	1.50	52,800	
				127,750	
	Contingencies and overhead		15%	19,250	
	Total				$147,000
2.	Relocation of Railroads and Utilities				
	Railroad relocation	0.44 mi.	Lump Sum	20,000	
	Contingencies and overhead		15%	3,000	
	Total				23,000
3.	Rights of Way and Land				
	Land	8 ac.	Lump Sum	5,000	
	Contingencies and overhead		15%	750	
	Total				5,750
4.	Highway Relocation				
	Park road	0.3 mi.	Lump Sum	15,000	
	Contingencies and overhead		15%	2,250	
	Total				17,250
5.	Grand Total Capital Cost				$193,000

The annual charge against this capital cost is about $8,994.

19. *Flood controlling effect of Plan B.*- The reductions in head losses effected by Plan B are similar to those obtained by Plan A, but much less. The loss from channel friction would have been reduced from 0.67 foot to 0.60 foot and the losses because of contraction and expansion would have been greatly reduced but not entirely eliminated as in the case of Plan A. The contraction loss would be reduced from 0.03 foot

to 0.01 foot and the expansion loss from 0.16 foot to 0.09 foot. The curvature loss would be reduced from 0.13 foot to 0.12 foot. The net result for Plan B is that the March 1936 maximum flood level would have been reduced only 0.16 foot at the Memorial Bridge and 0.10 foot at the Chicopee Bridge. The following table shows the probable stage reductions obtainable by Plan B at the two points for the March 1936 and the November 1927 floods. The modified profile resulting from Plan B is shown on Plate No. 161.

1936 AND 1927 FLOOD REDUCTIONS - PLAN B

Location of Index Stage	March 1936 Flood			November 1927 Flood		
	Nat. Elev.	Mod. Elev.	Red. Ft.	Nat. Elev.	Mod. Elev.	Red. Ft.
Memorial Bridge, Springfield	66.04	65.88	0.16	59.78	59.70	0.08
Chicopee Highway Bridge	69.45	69.35	0.10	62.39	62.38	0.01

20. Average annual benefits by Plan B.- The average annual reduction of direct loss, and its ratio to annual cost are shown in the following table for Plan B alone, Plan B after completion of reservoirs of the Comprehensive Plan, and Plan B after completion of Comprehensive Plan including reservoirs and dikes.

Damage Zone	Average Annual Reduction		
	Plan B Alone	Plan B after Comprehensive Reservoir Plan	Plan B after Comprehensive Reservoir Plan & Dikes
Springfield Dike Area	$2,220	$670	$0
W. Springfield Dike Area	1,230	300	0
Remaining Area affected by Channel Improvement	1,375	290	40
Totals	$4,825	$1,325	$40
Ratio Direct Benefit / Cost	0.535	0.147	0.004

With total benefits between 2 and 3 times the direct benefits, Plan B may be justified alone, but not in combination with any other flood control plan. As the Comprehensive Plan is economically justified, Plan B should be considered only in combination with it, and therefore it is not justified.

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(Report continued on following page)

STUDY OF CHANNEL IMPROVEMENT ABOVE HOLYOKE, MASSACHUSETTS

21. Description of reach.- The reach of river considered in this study extends from the highway bridge at Northampton, Massachusetts, to the Holyoke Dam in Holyoke, Massachusetts. The total length of the reach is about 11 miles, the river flowing in a generally southerly direction. About 5.1 miles below Northampton Bridge, the river flows through a gap in the Holyoke Range and the width of the flood plain is reduced abruptly from over 1-1/2 miles to about 1/2 mile. About 2.6 miles below this gap, the river enters the restricted section known as Smith Ferry Narrows and occupies the entire valley width of about 700 feet. The restricted section is 1.4 miles long and terminates in the pool of the Holyoke Dam. In 1936, the flood slope from Northampton Bridge to the gap in Holyoke Range was 0.37 foot per mile; from the gap to the Narrows, 1.00 foot per mile; and through the Narrows, 6.1 feet per mile. A general map of the river from Northampton to Holyoke is shown on Plate No. 163A. On this map are shown nine exaggerated cross sections so plotted that the March 1936 high water elevation coincides with the cross section line in each case. On Plate No. 163A are also shown the computed profiles for the March 1936 flood under existing channel conditions and with the channel improved by two plans.

22. Scope.- This study presents two plans, designated Plans A and B, for channel improvement in the restricted section known as Smith Ferry Narrows above Holyoke. Plan A provides for enlargement of the flood channel by widening the banks and excavating to low-water level, thereby increasing the minimum cross-sectional area about 25 per cent. Plan B provides for a similar enlargement by widening the banks and excavating to a depth of five feet below the low-water level, thereby increasing the minimum cross-sectional area about 34 per cent. Estimates of costs,

the reduction of flood heights, and the resultant benefits are presented for both plans.

23. Problem.- The channel constriction at Smith Ferry Narrows above Holyoke appears to be a major factor in backing up flood waters through Northampton. The high water profile for the March 1936 flood shows a decided increase in the flood slope through the Narrows; reduction of this flood slope would lower flood levels at points upstream, including Northampton. Such slope reduction can be accomplished by enlarging the flood channel through the most restricted section known as Smith Ferry Narrows, thereby increasing the carrying capacity and reducing the head losses caused by sudden changes in velocity.

24. Description of Plan A.- Plan A provides for enlargement of the flood channel through the Narrows by widening the banks and excavating down to the low water elevation. Most of the material excavated would come from the east bank of the river, thereby straightening the channel and effecting a more uniform cross section. For a distance of about 3,500 feet the cross-sectional area of the channel below the level of the 1936 flood crest is less than 22,000 square feet, with a minimum area of 16,000 square feet at the most constricted section. Because of the quantity of rock involved in excavating a channel of uniform carrying capacity through this reach, it does not appear economical to eliminate entirely the head losses from contraction and expansion. The line of cut according to this plan is so placed, however, that the March 1936 flood would have passed through this reach with a head loss of only 0.56 foot from contraction and expansion. The minimum cross-sectional area thus obtained is 20,100 square feet. It is estimated that this cut would require approximately 37,000 cubic yards of earth excavation and 335,000 cubic yards of rock excavation at a total cost, including rights of way and land, of $591,700. No relocation of highway or railroad is

contemplated. No borings have been made but the numerous outcroppings of ledge along this reach indicate that bedrock is covered by a relatively thin covering of earth. Details of the estimate follow:

ESTIMATE OF COST - PLAN A

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Preliminary investigation		Lump Sum	$ 1,000	
	Clearing	10.5 ac.	100	1,050	
	Excavation, earth	37,171 c.y.	0.25	9,293	
	Excavation, rock	334,539 c.y.	1.50	501,808	
				513,151	
	Contingencies and overhead		15%	75,973	
	Total				$590,124
2.	Rights of Way and Land				
	Land	18.5 ac.	75	1,388	
	Contingencies and overhead		15%	208	
	Total				1,596
3.	Highway and Railroad Relocation				None
4.	Grand Total Capital Cost				$591,720

The annual charge against this capital cost is about $27,600.

25. Flood controlling effect of Plan A.- In the reach of river from the foot of the Narrows to the gap in Holyoke Range, it is estimated that the head loss at the March 1936 crest from channel friction and curvature was 6.21 feet and the head loss from contraction, expansion and eddies combined was 4.93 feet. As a result of the channel enlargement proposed in Plan A it is estimated that for a flood equal to that of March 1936 the head loss from channel friction and curvature would be reduced to 5.74 feet and the head loss from contraction, expansion and eddies combined would be reduced to 2.87 feet. Although the crest of such a flood would be reduced 3.09 feet immediately above the enlarged channel, this reduction would diminish upstream and at the

Northampton highway bridge would be only 2.09 feet.

FLOOD REDUCTIONS - PLAN A

Index Station	March 1936			November 1927		
	Natural	Modified	Reduction	Natural	Modified	Reduction
Mile 89.5	125.56	122.47	3.09	119.19	117.73	1.46
Mile 97.2 (Northampton Bridge)	129.74	127.65	2.09	122.59	121.55	1.04
Mile 110.02 (Sunderland)	137.40	136.50	0.90	133.15	132.85	0.30

26. Average annual benefits by Plan A.- The average annual reduction of direct loss, and its ratio to annual cost are shown in the following table for Plan A alone, Plan A after completion of the reservoirs of the Comprehensive Plan, and Plan A after completion of Comprehensive Plan including reservoirs and dikes.

Damage Zone	Average Annual Reduction		
	Plan A Alone	Plan A after Comprehensive Reservoir Plan	Plan A after Comprehensive Reservoir Plan and Dikes
Northampton Dike Area A	$ 2,750	$ 480	$ 0
Northampton Dike Area B	820	160	0
Remaining area affected by channel improvement	7,230	455	455
Totals	$10,800	$1,095	$455
Ratio Direct Benefit / Cost	0.400	0.040	0.017

Since total benefits are between 2 and 3 times the direct benefits, it can be seen that Plan A may be justified alone but not if reservoirs and dikes are built. Since there is economic justification for the Comprehensive Plan including dikes at Northampton, Plan A cannot be justified.

27. <u>Description of Plan B</u>.- Plan B provides for a similar enlargement of the flood channel through the Narrows by widening the banks and excavating to a depth of five feet below the low water elevation. The line of cut according to this plan is so placed that the March 1936 flood would have passed through this reach with a head loss of only 0.26 feet due to contraction and expansion. The minimum cross section thus obtained is 21,500 square feet. It is estimated that this cut would require about 37,000 cubic yards of earth excavation and about 466,000 cubic yards of rock excavation at a total cost, including rights of way and land, of $1,200,000. No relocation of highway or railroad is contemplated. Details of the estimate follow:

<u>ESTIMATE OF COST - PLAN B</u>

Item No.	Item	Quantity	Unit Cost	Amount	Total
1.	Construction				
	Preliminary investigation		Lump Sum $	1,500	
	Clearing	10.5 ac.	100	1,050	
	Excavation, earth	37,171 c.y.	0.25	9,293	
	Excavation, rock	334,539 c.y.	1.50	501,808	
	Underwater excav., rock	132,200 c.y.	4.00	528,800	
				1,042,451	
	Contingencies and overhead		15%	156,368	
	Total				$1,198,819
2.	Rights of Way and Land				
	Land	18.5 ac.	75	1,388	
	Contingencies and overhead		15%	208	
	Total				1,596
3.	Highway and Railroad Relocation				None
4.	Grand Total Capital Cost				$1,200,415

The annual charge against this capital cost is about $56,000.

28. Flood controlling effect of Plan B.- As a result of the channel enlargement proposed in Plan B it is estimated that for a flood equal to that of March 1936 the head loss in this reach from channel friction and curvature would be reduced to 5.59 feet and the head loss because of contraction, expansion, and eddies combined would be reduced to 2.22 feet. Although the crest of such a flood would be reduced 4.14 feet immediately above the enlarged channel, this reduction would diminish upstream and at the Northampton highway bridge would be only 2.70 feet.

FLOOD REDUCTIONS - PLAN B

Index Station	March 1936			November 1927		
	Natural	Modified	Reduction	Natural	Modified	Reduction
Mile 89.5	125.56	121.42	4.14	119.19	117.04	2.15
Mile 97.2 (Northampton Bridge)	129.74	127.04	2.70	122.59	121.19	1.40
Mile 110.02	137.40	137.30	1.10	133.15	132.65	0.50

29. Average annual benefits by Plan B.- The average annual reduction of direct loss, and its ratio to annual cost are shown in the following table for Plan B alone, Plan B after completion of the reservoirs of the Comprehensive Plan, and Plan B after completion of Comprehensive Plan including reservoirs and dikes.

Damage Zone	Average Annual Reduction		
	Plan B Alone	Plan B after Comprehensive Reservoir Plan	Plan B after Comprehensive Reservoir Plan and Dikes
Northampton Dike Area A	$ 3,450	$ 670	$ 0
Northampton Dike Area B	980	185	0
Remaining area affected by channel improvement	8,740	715	715
Totals	$13,170	$1,570	$715
Ratio Direct Benefit / Cost	0.238	0.028	0.013

Although total benefits may be 2 or 3 times the direct benefits, it can be seen that Plan A is not justified alone nor in combination with any other flood control plan.

(Report continued on following page)

WELLS RIVER BAR AT WELLS RIVER, VERMONT

30. Description of reach.- The reach of river studied extends downstream from the mouth of the Wells River for a distance of 1,600 feet. The Wells River flows in from the Vermont side about 1,300 feet below the mouth of the Ammonoosuc River. The 1936 flood slope throughout this reach and for some miles below was very flat, about 0.3 foot per mile, but immediately above, a series of narrows caused it to increase abruptly, rising about ten feet in a distance of half a mile.

31. Problem.- About 300 feet below the mouth of the Wells River, the 1927 flood deposited a gravel bar that has been increased by subsequent floods. This bar turns the current towards the Vermont shore, so that it undermines the steep river bank. It is estimated that approximately 75 feet of bank has been eroded since 1927, at least half of the erosion occurring in the 1936 flood. The swift current in the latter flood carried away one house and damaged six others on the Vermont shore. In the March 1936 flood the cross-sectional area at the most restricted section of the bar was about 14,600 square feet and the maximum velocity through this section was about 8.0 feet per second.

32. Plan studied.- By excavating part of the bar this restricted area can be increased 35% and as a result the maximum velocity can be reduced to about 5.8 feet per second and its direction changed away from the shore. It is estimated that about 77,400 cubic yards of gravel must be removed at a total cost of $31,500. This work would give a few houses incomplete protection but at a cost greater than their total valuation. Because of the flat slope throughout the

reach and the steep slope above it, no appreciable reduction of stage can be expected at points upstream. It is very likely, furthermore, that the channel excavated in the gravel bar would be filled with sand and gravel in the early stages of a large flood so that any benefit that it might convey would be of short duration. Since the flood-controlling effect is negligible, this plan cannot be justified as a flood control measure.

SECTION 6

TABLE REFERENCE

TABLE 55

TYPICAL COMPUTATION OF NATURAL CHANNEL VELOCITY HEAD

MARCH, 1936, HIGH WATER - PAPER ROCK TO HARTFORD

Reach No.	Mean Elevation Ft.	Mean Channel Conveyance K_c	Mean Total Conveyance K_T	Total Discharge C.F.S.	Channel Discharge C.F.S.	Channel Area Sq.Ft.	Channel Velocity Ft./Sec.	Channel Velocity Head Ft.
15	25.60	780,000	792,000	282,000	278,000	56,000	4.96	0.38
14	26.05	630,000	630,000	282,000	282,000	38,500	7.32	0.83
13	27.55	605,000	605,000	282,000	282,000	34,000	8.30	1.07
12	29.30	612,000	772,000	282,000	224,000	36,000	6.22	0.60
11	30.30	860,000	860,000	282,000	282,000	48,500	5.81	0.52
10	30.80	740,000	1,092,000	282,000	191,000	44,500	4.29	0.29
9	31.20	940,000	1,152,000	282,000	231,000	63,000	3.67	0.21
8	32.03	800,000	986,000	282,000	228,000	45,000	5.08	0.40
7	32.90	1,200,000	1,670,000	282,000	203,000	68,500	2.96	0.14
6	33.40	890,000	914,000	282,000	274,000	54,200	5.07	0.40
5	34.50	810,000	888,000	282,000	260,000	44,200 (O.B.)	5.90	0.54
4	35.70	-	1,260,000	282,000	282,000	246,000	1.15	0.02
3	36.60	860,000	1,171,000	282,000	207,000	53,000	3.91	0.23
2	36.80	830,000	1,278,000	282,000	184,000	50,000	3.70	0.21
1	37.20	815,000	859,000	282,000	267,000	45,000	5.93	0.55

TABLE 56.

TYPICAL COMPUTATION OF NATURAL WATER SURFACE PROFILE
MARCH, 1936, HIGH WATER - PAPER ROCK TO THOMPSONVILLE.

Reach No.	Station	Length of Reach Low Water Feet	Length of Reach High Water Feet	Total Conveyance K_T	Coefficient of friction	Total Discharge Q_T c.f.s.	HEAD LOSSES: Friction	HEAD LOSSES: Curvature	Channel Velocity Head	Change in Channel Velocity Head	HEAD LOSSES: Contraction	HEAD LOSSES: Expansion	HEAD LOSSES: Eddy	Total Rise in W.S. in Reach	Elevation Ends of Reach
	0								.30						25.40
15		4,750	4,750	792,000	.028	282,000	0.47	0.09	.38	-.29	--	0.12	[illegible]	0.39	
	4,750								.59						25.79
14		4,490	4,490	630,000	.028	282,000	0.71	0.14	.83	-.41	--	0.16	--	0.60	
	9,240								1.00						26.39
13		6,340	6,340	605,000	.028	282,000	1.08	0.22	1.07	.15	.03	--	.87	2.35	
	15,580								.85						28.74
12		7,390	7,390	772,000	.028	282,000	0.77	0.15	.60	-.25	.05	--	--	1.22	
	22,970								.60						29.96
11		4,490	4,490	860,000	.028	282,000	0.38	0.06	.52	.18	.04	--	--	0.66	
	27,460								.42						30.62
10		2,640	2,640	1,092,000	.028	282,000	0.14	0.03	.29	.20	.04	--	--	0.41	
	30,100								.22						31.03
9		6,600	6,600	1,152,000	.028	282,000	0.31	0.06	.21	-.07	--	.03	--	0.33	
	36,700								.29						31.36
8		8,180	8,180	988,000	.028	282,000	0.52	0.10	.40	-.01	--	--	.72	1.33	
	44,880								.30						32.69
7		7,660	7,660	1,670,000	.028	282,000	0.17	0.04	.14	-.05	.01	--	--	0.27	
	52,540								.25						32.96
6		11,350	11,350	914,000	.028	282,000	0.87	0.17	.40	-.23	--	.09	--	0.90	
	63,890								.48						33.86
5		7,230	7,230	888,000	.028	282,000	0.58	0.12	.54	-.05	--	.02	--	0.67	
	71,120								.53						34.53
4		36,540	19,800	1,260,000	.028	282,000	0.78	0.16	.02	.23	.05	--	--	1.22	
	90,920								.30						35.75
3		15,840	15,840	1,171,000	.028	282,000	0.72	0.14	.23	.05	.01	--	--	0.92	
	106,760								.25						36.67
2		5,070	5,070	1,278,000	.028	282,000	0.19	--	.21	-.11	--	.04	--	0.12	
	111,830								.36						36.79
1		4,490	4,490	859,000	.028	282,000	0.38	0.08	.55	-.18	--	.07	--	0.35	
	116,320								.54						37.14
B	177,520	--	55,200	1,100,000	.028	282,000	2.82	0.56	--	--	--	--	--	3.38	40.52
A	198,420	--	26,900	330,000	.028	282,000	15.40	3.07	--	--	--	--	--	18.47	58.99

TABLE 57

TYPICAL COMPUTATION OF MODIFIED CHANNEL VELOCITY HEAD

MARCH, 1936, HIGH WATER - PAPER ROCK TO HARTFORD

Reach No.	Mean Elevation Ft.	Mean Channel Conveyance Kc.	Mean Total Conveyance K_T	Total Discharge C.F.S.	Channel Discharge C.F.S.	Channel Area Sq.Ft.	Channel Velocity Ft./Sec.	Channel Velocity Head Ft.
15	25.60	780,000	792,000	282,000	278,000	56,000	4.96	.38
14	26.10	635,000	635,000	282,000	282,000	39,200	7.20	.81
13	27.10	745,000	745,000	282,000	282,000	39,750	7.10	.79
12	28.20	582,000	730,000	282,000	225,000	35,400	6.35	.63
11	29.10	820,000	820,000	282,000	282,000	47,500	5.94	.55
10	29.60	705,000	1,030,000	282,000	193,000	43,200	4.47	.31
9	29.95	890,000	1,066,000	282,000	231,000	60,000	3.85	.23
8	30.90	745,000	909,000	282,000	231,000	43,600	5.30	.44
7	31.86	1,130,000	1,570,000	282,000	203,000	66,600	3.05	.14
6	32.40	850,000	870,000	282,000	276,000	53,000	5.20	.42
5	33.30	785,000	853,000	282,000	260,000	43,000 (O.B.)	5.90	.54
4	34.40	-	1,150,000	282,000	282,000	228,000	1.24	.02
3	35.70	825,000	1,109,000	282,000	210,000	52,000	4.04	.25
2	36.25	790,000	1,217,000	282,000	183,000	49,000	3.74	.22
1	36.50	795,000	835,000	282,000	269,000	44,500	6.04	.56

TABLE 58

TYPICAL COMPUTATION OF MODIFIED WATER SURFACE PROFILE

MARCH, 1936, HIGH WATER - PAPER ROCK TO THOMPSONVILLE

Reach No.	Station	Length of Reach Low Water Feet	Length of Reach High Water Feet	Total Conveyance K_T	Coefficient of friction	Total Discharge Q_T c.f.s.	HEAD LOSSES Friction	HEAD LOSSES Curvature	Channel Velocity Head	Change in Channel Velocity Head	HEAD LOSSES Contraction	HEAD LOSSES Expansion	HEAD LOSSES Eddy	Total rise in W.S. in reach	Elevation ends of reach
	0								.30						25.40
15		4750	4750	792,000	.028	282,000	0.47	0.09	.38	-.29	--	.12	--	.39	
	4750								.59						25.79
14		4490	4490	635,000	.028	282,000	0.70	0.14	.81	-.26	--	.10	--	.68	
	9240								.85						26.47
13		6340	6340	745,000	.0278	282,000	.71	.14	.79	.20	.04	--	--	1.09	
	15580								.65						27.56
12		7390	7390	730,000	.0278	282,000	.87	.17	.63	.05	.01	--	--	1.10	
	22970								.60						28.66
11		4490	4490	820,000	.0278	282,000	.42	.08	.55	.15	.03	--	--	.68	
	27460								.45						29.34
10		2640	2640	1,030,000	.0278	282,000	.16	.03	.31	.23	.05	--	--	.47	
	30100								.22						29.81
9		6600	6600	1,086,000	.0278	282,000	.35	.07	.23	-.13	--	.05	--	.34	
	36700								.35						30.15
8		8180	8180	909,000	.0278	282,000	.62	.12	.44	.05	.01	--	.79	1.59	
	44880								.30						31.74
7		7660	7660	1,570,000	.0278	282,000	.19	.04	.14	.02	--	--	--	.25	
	52540								.28						31.99
6		11350	11350	870,000	.0278	282,000	.94	.19	.42	-.24	--	.10	--	.99	
	63890								.52						32.98
5		7230	7230	853,000	.0278	282,000	.62	.12	.54	-.04	--	.02	--	.72	
	71120								.56						33.70
4		36540	19800	1,150,000	.0278	282,000	.93	.19	.02	.36	.07	--	--	1.55	
	90920								.20						35.25
3		15840	15840	1,109,000	.0278	282,000	.80	.16	.25	0	--	--	--	.96	
	106760								.20						36.21
2		5070	5070	1,217,000	.0278	282,000	.22	--	.22	-.20	--	.08	--	.10	
	111830								.40						36.31
1		4490	4490	835,000	.0278	282,000	.40	.08	.56	-.14	--	.06	--	.40	
	116320								.54						36.71
B		--	55200	1,080,000	.0279	282,000	2.93	.59	--	--	--	--	--	3.52	
	171520														40.23
A		--	26900	328,000	.028	282,000	15.63	3.13	--	--	--	--	--	18.76	
	198420														58.99

TABLE 59

TYPICAL COMPUTATION OF MODIFIED CHANNEL VELOCITY HEAD

MARCH, 1936, HIGH WATER - GILDERSLEEVE ISLAND TO HARTFORD

Reach No.	Mean Elevation Ft.	Channel Conveyance K_c	Total Conveyance K_T	Total Discharge C.F.S.	Channel Discharge C.F.S.	Channel Area Sq.Ft.	Channel Velocity Ft./Sec.	Channel Velocity Head Ft.
7	29.25	1,000,000	1,374,000	282,000	205,000	62,000	3.31	.17
6	30.[illegible]	765,000	781,000	282,000	276,000	49,500	5.58	.47
5	31.[illegible]	725,000	77[illegible],000	282,000	266,000	41,000 (O.B.)	6.5[illegible]	.66
4	32.3	-	985,000	282,000	282,000	208,000	1.35	.03
3	33.9	765,000	984,000	282,000	219,000	49,500	4.43	.30
2	34.6	700,000	1,088,000	282,000	182,000	45,000	4.05	.25
1	34.8	760,000	798,000	282,000	269,000	43,000	6.25	.60

TABLE 60

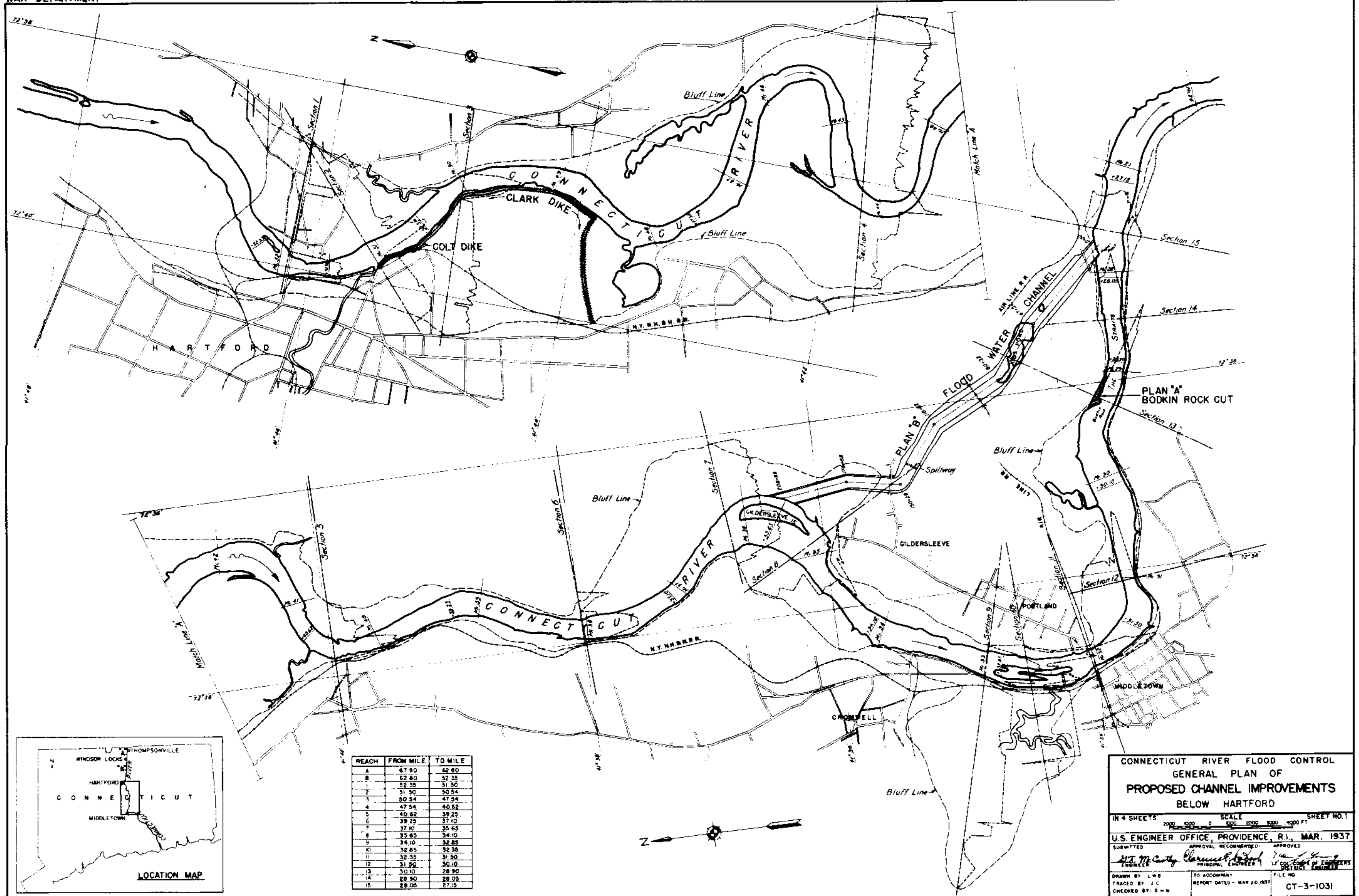
TYPICAL COMPUTATION OF MODIFIED WATER SURFACE PROFILE

MARCH, 1936, HIGH WATER - GILDERSLEEVE ISLAND TO THOMPSONVILLE

Reach No.	Station	Length of Reach Low Water Feet	Length of Reach High Water Feet	Total Conveyance K_T	Coefficient of Friction	Total Discharge Q_T c.f.s.	HEAD LOSSES: Friction	HEAD LOSSES: Curvature	Channel Velocity Head	Change in Channel Velocity Head	HEAD LOSSES: Contraction	HEAD LOSSES: Expansion	HEAD LOSSES: Eddy	Total Rise in W.S. in Reach	Elevation Ends of Reach
	44880								.40						29.00
7		7660	7660	1,374,000	.0272	282,000	.24	.05	.17	.10	.02	--	--	.41	
	52540								.30						29.41
6		11350	11350	781,000	.0272	282,000	1.09	.22	.47	-.26	--	.11	--	1.16	
	63890								.56						30.57
5		7230	7230	770,000	.0273	282,000	.72	.14	.66	-.05	--	.02	--	.83	
	71120								.61						31.40
4		36540	19800	985,000	.0274	282,000	1.22	.24	.03	.40	.02	--	--	1.88	
	90920								.21						33.28
3		15840	15840	984,000	.0274	282,000	.99	.20	.30	-.05	--	.02	--	1.16	
	106760								.26						34.44
2		5070	5070	1,088,000	.0275	282,000	.26	.05	.25	-.14	.03	--	--	.20	
	111830								.40						34.64
1		4490	4490	798,000	.0275	282,000	.43	.09	.60	-.17	.03	--	--	.38	
	116320								.57						35.02
B		--	55200	1,050,000	.0277	282,000	3.08	.62	--	--	--	--	--	3.70	
	171520														38.72
A		--	26900	316,000	.028	282,000	16.90	3.37	--	--	--	--	--	20.27	
	198420														58.99

SECTION 6

PLATE REFERENCE



REACH	FROM MILE	TO MILE
A	67.90	62.80
B	62.80	52.35
1	52.35	51.50
2	51.50	50.54
3	50.54	47.54
4	47.54	40.62
5	40.62	39.25
6	39.25	37.10
7	37.10	35.65
8	35.65	34.10
9	34.10	32.85
10	32.85	32.35
11	32.35	31.50
12	31.50	30.10
13	30.10	28.90
14	28.90	28.05
15	28.05	27.15

CONNECTICUT RIVER FLOOD CONTROL
GENERAL PLAN OF
PROPOSED CHANNEL IMPROVEMENTS
BELOW HARTFORD

IN 4 SHEETS — SCALE 2000 1000 0 1000 2000 3000 4000 FT — SHEET NO. 1

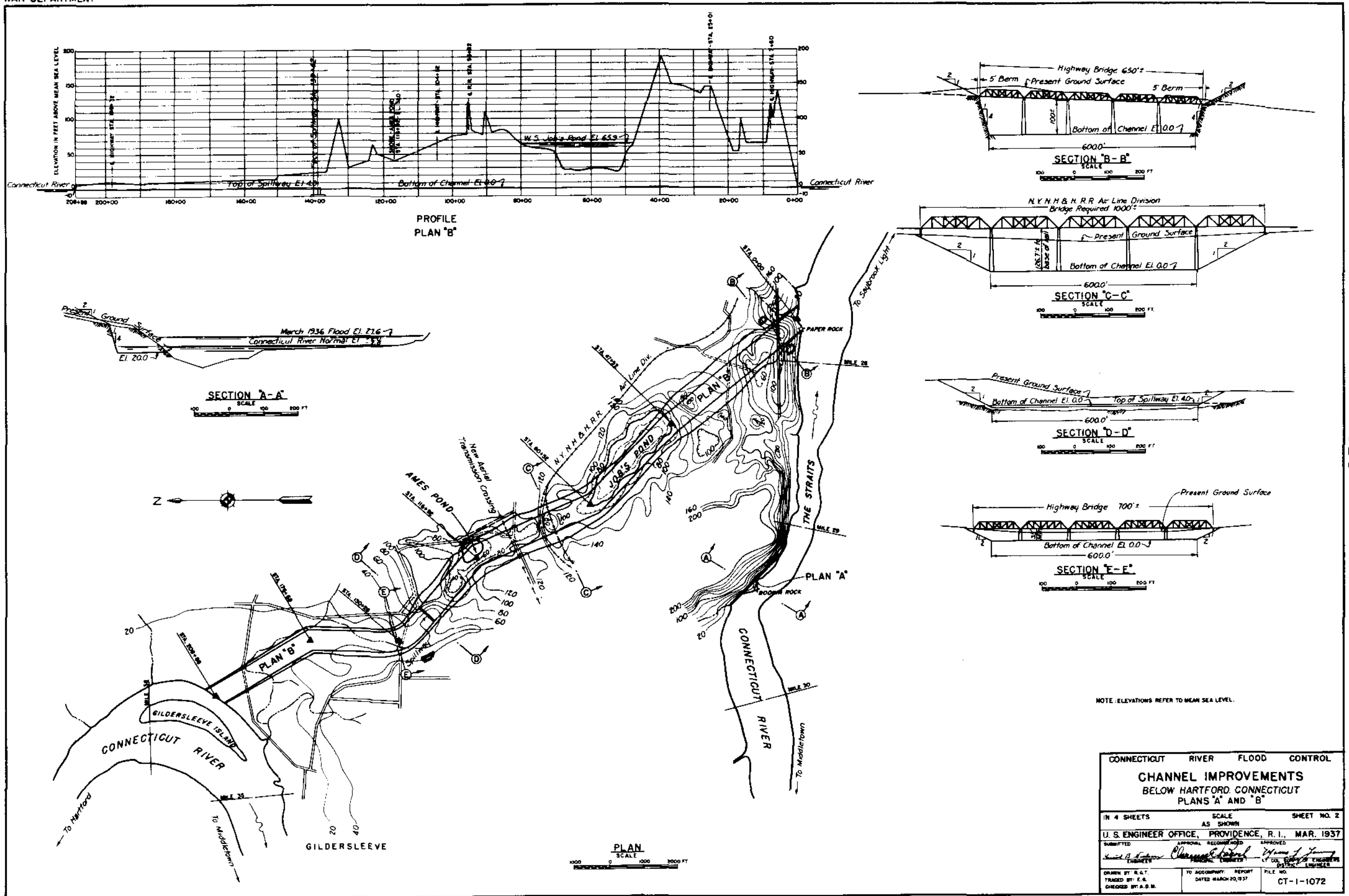
U.S. ENGINEER OFFICE, PROVIDENCE, R.I., MAR. 1937

SUBMITTED: G.T. McCarthy, ENGINEER
APPROVAL RECOMMENDED: Clarence R. [illegible], PRINCIPAL ENGINEER
APPROVED: [illegible], LT. COL., CORPS OF ENGINEERS, DISTRICT ENGINEER

DRAWN BY: L.W.B.
TRACED BY: J.C.
CHECKED BY: G.H.N.

TO ACCOMPANY REPORT DATED - MAR. 20, 1937

FILE NO. CT-3-1031

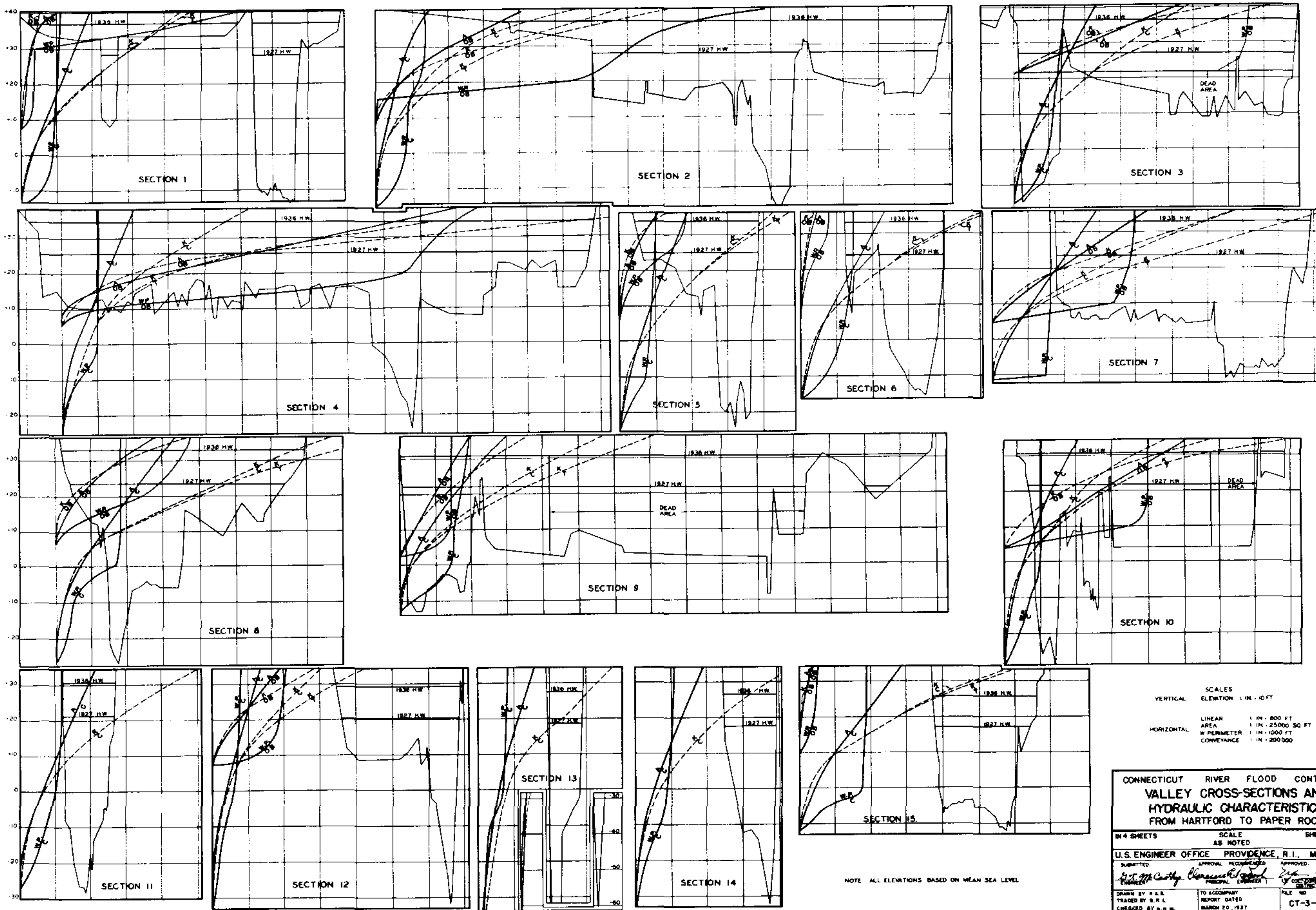


ELEVATION IN FEET ABOVE MEAN SEA LEVEL
Connecticut River
Top of Spillway El. 4.0
Bottom of Channel El. 0.0
W. S. Job's Pond El. 65.9
PROFILE
PLAN "B"
Highway Bridge 650'±
5' Berm
Present Ground Surface
Bottom of Channel El. 0.0
600.0'
SECTION "B-B"
SCALE
N.Y.N.H.&H.R.R. Air Line Division
Bridge Required 1000'±
SECTION "C-C"
March 1936 Flood El. 27.6
Connecticut River Normal El. 3.8
El. 20.0
SECTION "A-A"
Present Ground Surface
Top of Spillway El. 4.0
SECTION "D-D"
Highway Bridge 700'±
SECTION "E-E"
AMES POND
JOB'S POND
PLAN "B"
PLAN "A"
New Aerial Transmission Crossing
N.Y.N.H.&H.R.R. Air Line Div.
PAPER ROCK
BODKIN ROCK
THE STRAITS
To Saybrook Light
CONNECTICUT RIVER
GILDERSLEEVE ISLAND
GILDERSLEEVE
To Hartford
To Middletown
Spillway
MILE 28
MILE 29
MILE 30
MILE 31
PLAN
SCALE
NOTE: ELEVATIONS REFER TO MEAN SEA LEVEL.
CONNECTICUT RIVER FLOOD CONTROL
CHANNEL IMPROVEMENTS
BELOW HARTFORD, CONNECTICUT
PLANS "A" AND "B"
IN 4 SHEETS
SCALE AS SHOWN
SHEET NO. 2
U. S. ENGINEER OFFICE, PROVIDENCE, R. I., MAR. 1937
SUBMITTED
ENGINEER
APPROVAL RECOMMENDED
PRINCIPAL ENGINEER
APPROVED
LT. COL. CORPS OF ENGINEERS
DISTRICT ENGINEER
TO ACCOMPANY REPORT DATED MARCH 20, 1937
FILE NO.
CT-1-1072

- 252 -

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY



CONNECTICUT RIVER FLOOD CONTROL

VALLEY CROSS-SECTIONS AND HYDRAULIC CHARACTERISTICS FROM HARTFORD TO PAPER ROCK

IN 4 SHEETS | SCALE AS NOTED | SHEET NO. 3

U.S. ENGINEER OFFICE PROVIDENCE, R.I., MAR. 1937

SUBMITTED: G. T. McCarthy, ENGINEER
APPROVAL RECOMMENDED: Clarence R. Pond, PRINCIPAL ENGINEER
APPROVED: [signature], LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

DRAWN BY R.A.B.
TRACED BY S.R.L.
CHECKED BY G.H.M.

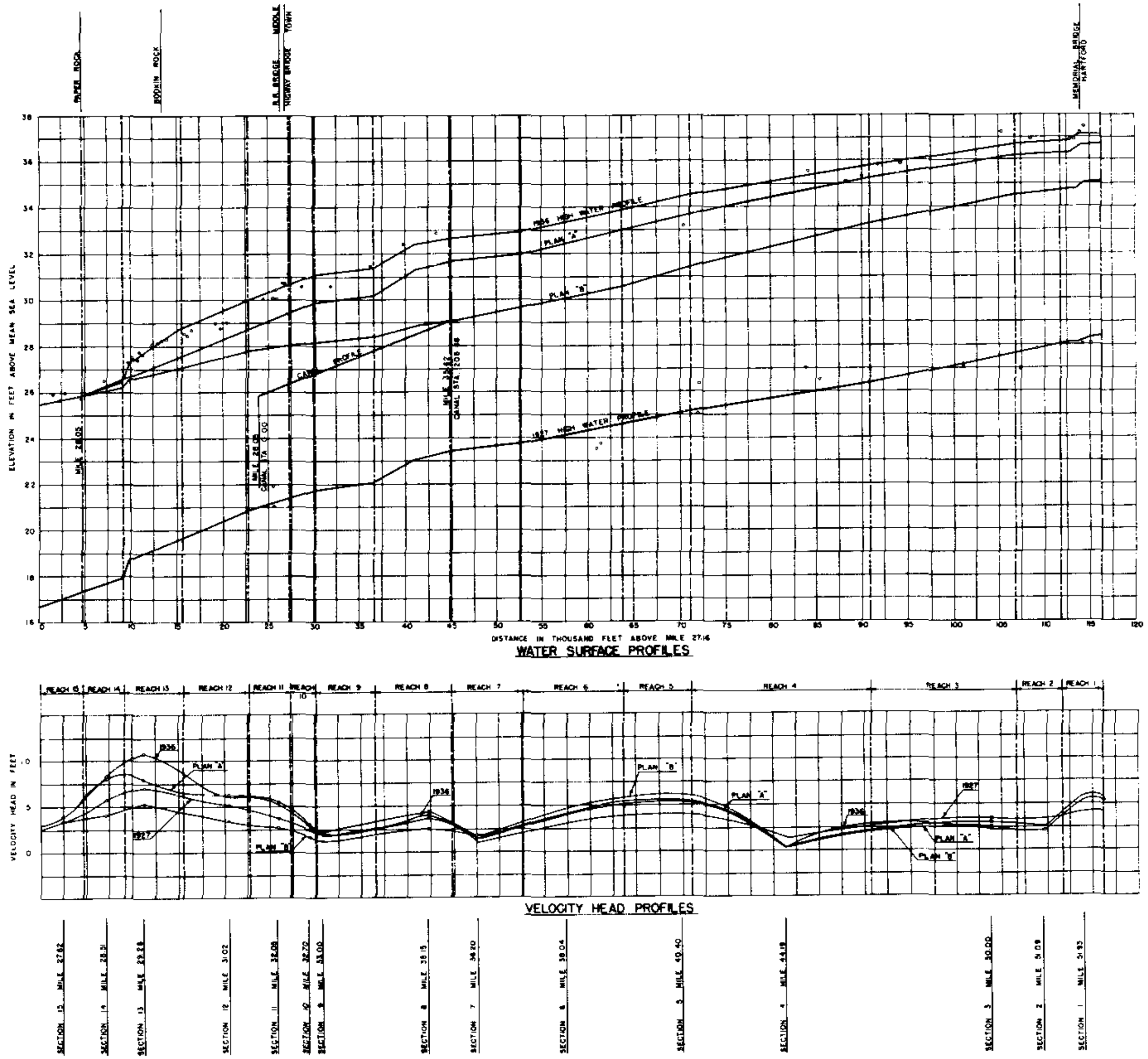
TO ACCOMPANY REPORT DATED MARCH 20, 1937

FILE NO. CT-3-1033

SEC. 6 — PLATE NO. 159

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



NOTE
HIGH WATER MARKS SHOWN THUS ◦

CONNECTICUT RIVER FLOOD CONTROL

NATURAL AND MODIFIED PROFILES

FROM HARTFORD TO PAPER ROCK

IN 3 SHEETS | SCALE AS SHOWN | SHEET NO 2

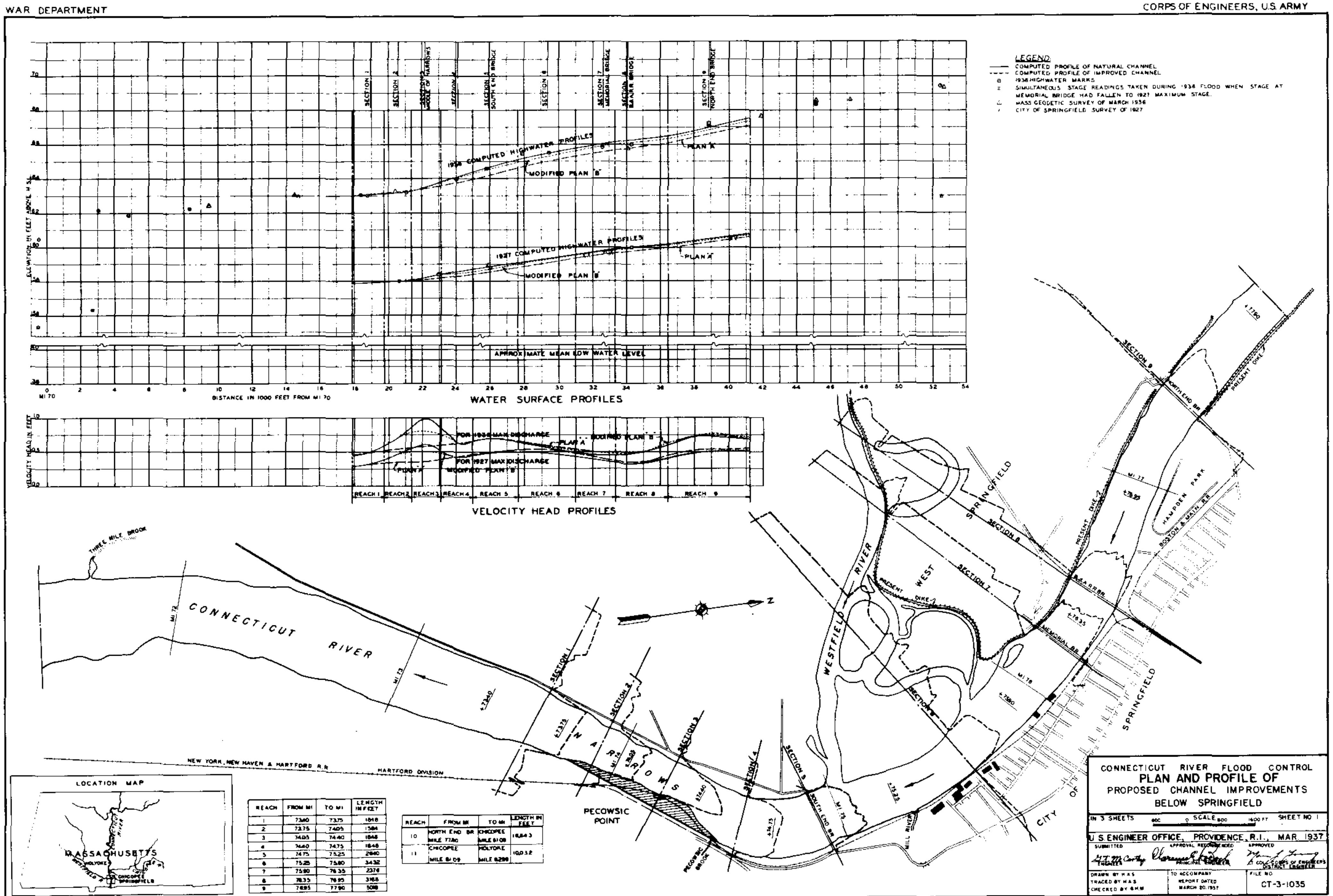
U.S. ENGINEER OFFICE PROVIDENCE R.I., MAR. 1937

SUBMITTED: G.T. McCarthy, ENGINEER
APPROVAL RECOMMENDED: Clarence P. [illegible], PRINCIPAL ENGINEER
APPROVED: [illegible], LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

DRAWN BY J.O.M.
TRACED BY H.E.W.
CHECKED BY R.H.M.

TO ACCOMPANY REPORT DATED MARCH 20, 1937

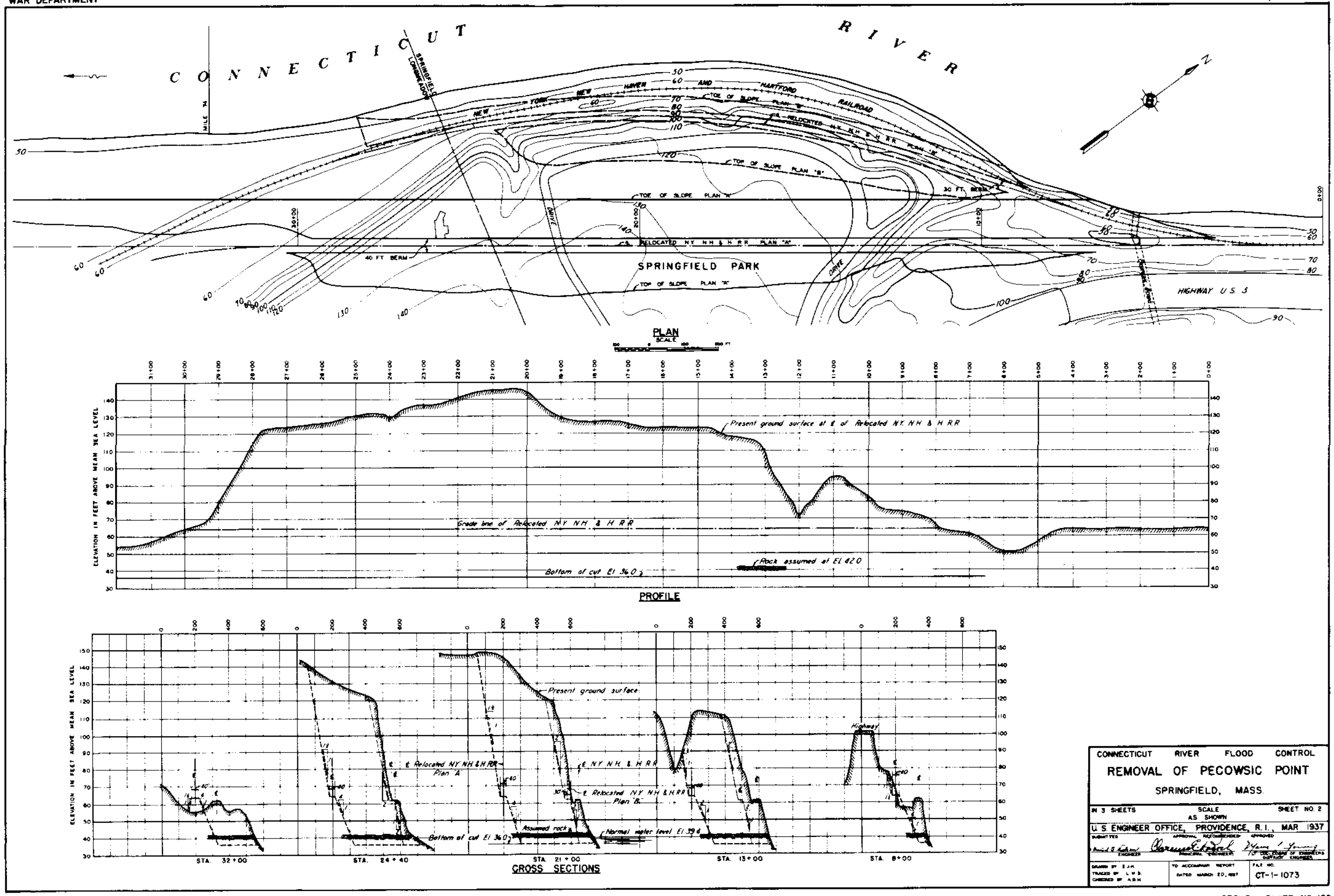
FILE NO. CT-3-1034

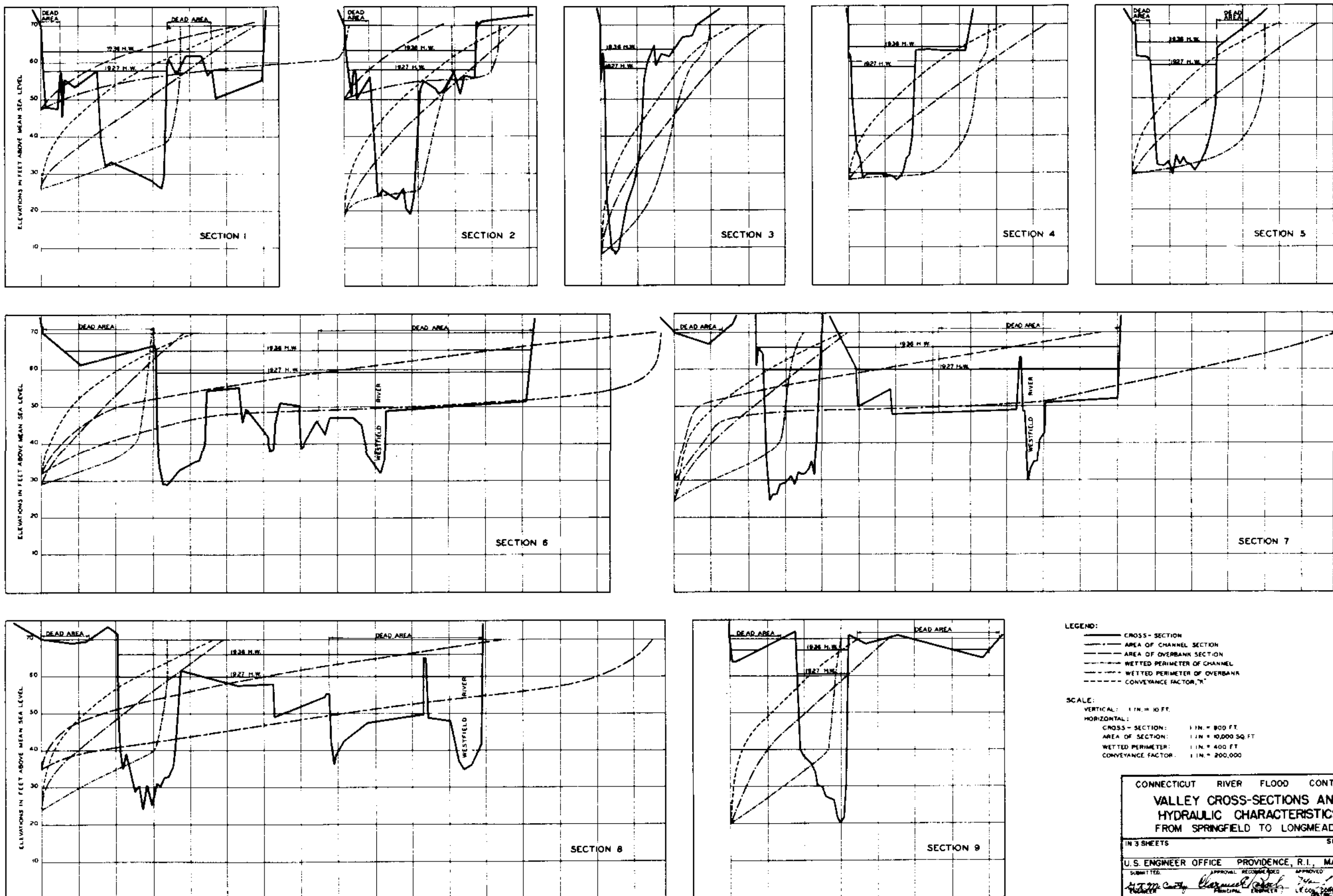


REACH	FROM MI	TO MI	LENGTH IN FEET
1	73.40	73.75	1848
2	73.75	74.05	1584
3	74.05	74.40	1848
4	74.40	74.75	1848
5	74.75	75.25	2640
6	75.25	75.80	3432
7	75.80	76.35	2374
8	76.35	76.95	3168
9	76.95	77.90	5018

REACH	FROM MI	TO MI	LENGTH IN FEET
10	NORTH END BR MILE 77.80	CHICOPEE MILE 81.08	16,843
11	CHICOPEE MILE 81.09	HOLYOKE MILE 82.98	10,032

SEC. 6—PLATE NO. 161


CONNECTICUT RIVER
SPRINGFIELD LONGMEADOW
MILE 74
NEW YORK NEW HAVEN AND HARTFORD RAILROAD
TOE OF SLOPE PLAN "B"
℄ RELOCATED N.Y. N.H. & H. R.R. PLAN "B"
TOP OF SLOPE PLAN "B"
TOE OF SLOPE PLAN "A"
30 FT. BERM
℄ RELOCATED N.Y. N.H. & H. R.R. PLAN "A"
40 FT BERM
SPRINGFIELD PARK
TOP OF SLOPE PLAN "A"
DRIVE
HIGHWAY U.S. 5
PLAN
SCALE
Present ground surface at ℄ of Relocated N.Y. N.H. & H.R.R.
Grade line of Relocated N.Y. N.H. & H.R.R.
Rock assumed at El. 42.0
Bottom of cut El. 36.0
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
PROFILE
Present ground surface
℄ Relocated N.Y. N.H. & H.R.R. Plan "A"
℄ N.Y. N.H. & H.R.R.
℄ Relocated N.Y. N.H. & H.R.R. Plan "B"
Highway
Assumed rock
Normal water level El. 39.6
Bottom of cut El. 36.0
STA. 32+00
STA. 24+40
STA. 21+00
STA. 13+00
STA. 8+00
CROSS SECTIONS
CONNECTICUT RIVER FLOOD CONTROL
REMOVAL OF PECOWSIC POINT
SPRINGFIELD, MASS.
IN 3 SHEETS
SCALE AS SHOWN
SHEET NO. 2
U.S. ENGINEER OFFICE, PROVIDENCE, R.I., MAR. 1937
CT-1-1073



LEGEND:
- CROSS - SECTION
- AREA OF CHANNEL SECTION
- AREA OF OVERBANK SECTION
- WETTED PERIMETER OF CHANNEL
- WETTED PERIMETER OF OVERBANK
- CONVEYANCE FACTOR, "K"

SCALE:
VERTICAL: 1 IN. = 10 FT.
HORIZONTAL:
CROSS - SECTION: 1 IN. = 800 FT.
AREA OF SECTION: 1 IN. = 10,000 SQ. FT.
WETTED PERIMETER: 1 IN. = 400 FT.
CONVEYANCE FACTOR: 1 IN. = 200,000

CONNECTICUT RIVER FLOOD CONTROL

VALLEY CROSS-SECTIONS AND HYDRAULIC CHARACTERISTICS FROM SPRINGFIELD TO LONGMEADOW

IN 3 SHEETS — SHEET NO. 3

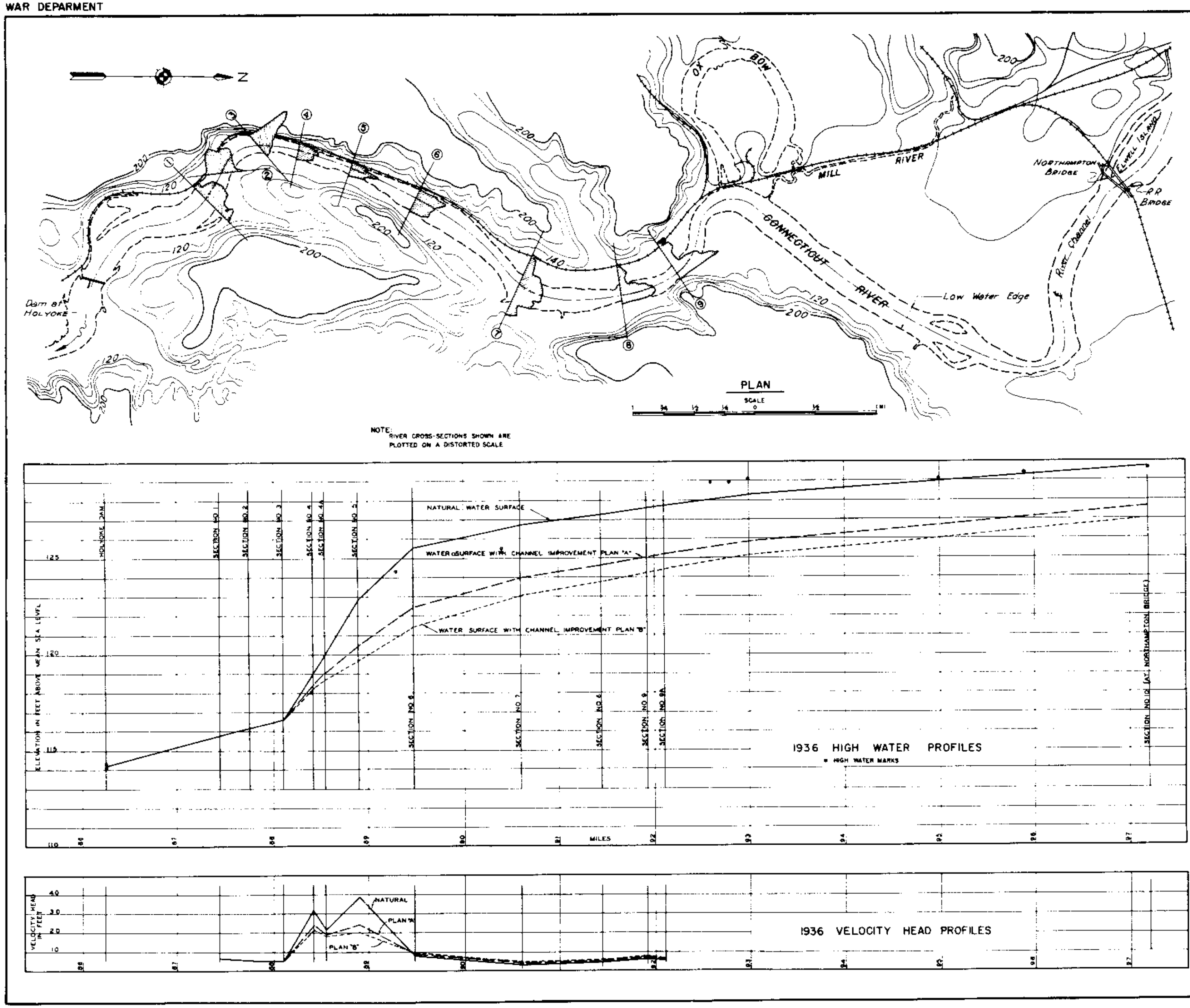
U.S. ENGINEER OFFICE PROVIDENCE, R.I., MAR. 1937

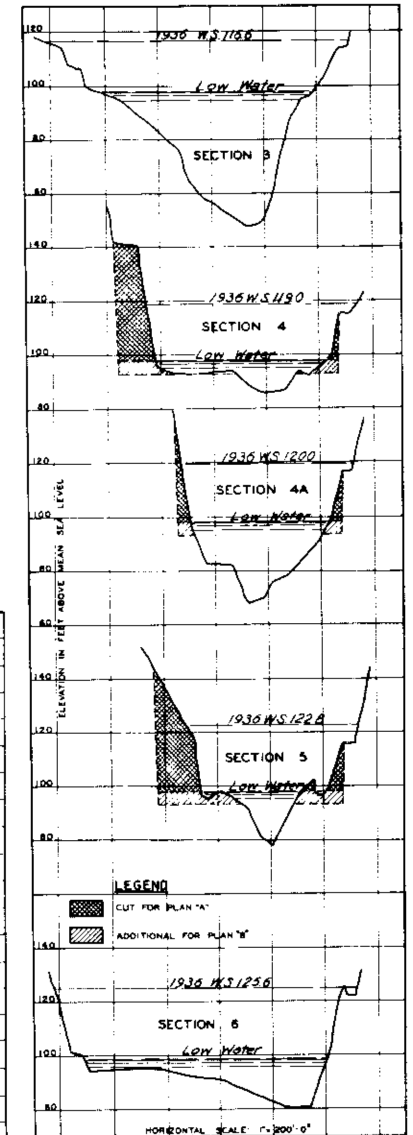
SUBMITTED: H. T. McCarthy, ENGINEER
APPROVAL RECOMMENDED: PRINCIPAL ENGINEER
APPROVED: LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

DRAWN BY R.R.G.
TRACED BY J.B.M.
CHECKED BY G.H.M.

TO ACCOMPANY REPORT DATED MARCH 20, 1937

FILE NO. CT-3-1037





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CONNECTICUT RIVER FLOOD CONTROL

CHANNEL IMPROVEMENT STUDY

ABOVE HOLYOKE

IN 1 SHEET | SCALE AS SHOWN | SHEET NO. 1

U. S. ENGINEER OFFICE, PROVIDENCE, R. I., MAR. 1937

SUBMITTED | APPROVAL RECOMMENDED | APPROVED

DRAWN BY E.R. TRACED BY F.J.S. CHECKED BY C.N.TH.

TO ACCOMPANY REPORT DATED MARCH 20, 1937

FILE NO. CT-3-1038